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SOILS AND FERTILISERS.*

DURING the last few years there has been a marked change in the approach to problems of soil fertility. It is being realised in many countries that the conservation of soil and the maintenance or improvement of its fertility are matters of vital public concern, which can no longer be safely left to the blind interplay of individual interests. Organised surveys and investigations form essential parts of the plans for land reclamation and increased agricultural production in the totalitarian states. In the democratic ones the more recent subsidies to agriculture have been designed to bear more directly on the enhancement of soil fertility.

In Great Britain the early subsidies, quotas and marketing regulations were intended to improve the prices of individual crops, *e.g.*, wheat, sugar beet, or potatoes, or animal products, *e.g.*, milk, bacon, meat, but in the Agricultural Act of 1937 assistance was given to farmers in the purchase of materials for improving their land. For a term of years the Government will pay one-half of the cost at the farm of lime in all its forms and one-quarter of the cost of basic slag. A Land Fertility Committee, with Lord Cranworth as Chairman, was set up to administer this section of the Act, which came into operation in 1937. A levy of 2*d.* per ton of lime and slag will be paid into a fund for the purpose of promoting research, investigation and instruction, on the use of lime or basic slag as a means of promoting the fertility of the soil. The liming subsidy has greatly increased the requests by farmers for soil analysis, and it is likely that this will be followed by requests for similar help in other manurial problems.

In the United States a vast Soil Conservation Service has been built up to undertake the research and surveys and the technical and educational work required in connection with ambitious schemes of control and subsidy. It is recognised that much of the wastage has resulted directly from the uncontrolled exploitation of land for immediate returns, and farmers are now being paid to refrain from growing those crops which allow rapid soil deterioration. In the tropics, the ravages of soil erosion are receiving more attention. Clean cultivation of rubber has given

* E. M. Crowther. *Applied Chemistry Reports*, XXII, p. 573.

way to contour terracing, silt pitting, and the more general use of cover crops. In the newly developed areas, where cotton and other cash crops are being introduced experimentally, it is realised that there is little hope of enduring success unless rotations are found by which the productivity of the land can be maintained. Many attempts are being made to replace the native methods of shifting cultivation and nomadic stock keeping by systems of mixed farming, providing food for both man and beast, as well as a saleable crop, which will stand transport costs.

The new orientation emphasises the fundamental importance of the structure of the soil in relation to the environmental conditions. In virgin land, whether jungle or grass steppe, the forces of rain and wind are checked by the canopy or herbage and by the broken soil surface. The masses of ramifying living roots periodically dry out the soil into crumbs, and the decaying ones provide both channels for water movement and organic colloids which appear to make the crumbs more stable. An active soil fauna, notably worms and insects, plays an important part in building up the structure. Clearing and cultivation inevitably destroy both the protective cover and the active roots and, at the same time, they speed up the decomposition of plant and animal residues in the soil. The soil becomes more compact, water runs off the surface, and soil degradation proceeds at an accelerating rate, whilst the fertile valleys in the lower grounds are exposed to increasing damage by flooding as the rivers steadily silt up. In drier areas much of the richer surface soil is lost in dust storms. The rate of decline naturally varies widely between different areas. The analysis of the processes involved calls for systematic attack from many angles, and the introduction of effective remedies may require drastic alteration in administrative methods, or even in the whole social and economic system.

The emphasis on the structure of soils as a vital factor in their evolution or degradation is undoubtedly a great improvement on the older view which merely stated that the nitrogen content was falling and that something must be done to maintain the supply of humus. In temperate countries with well-established agricultural systems, there is a traditional technique for offsetting some of the inevitable losses by returning to the land large amounts of plant residues and animal wastes, as in farmyard manure and composts. With increasing mechanisation and rising labour costs some important sources of supplies are failing, and it is becoming more necessary than ever to handle the available materials efficiently. In Germany systematic attempts are being made to improve the methods of handling dung on the small peasant farms. In the United Kingdom and overseas renewed interest in the making of composts has been aroused by the powerful advocacy of Sir Albert Howard.

Soil and agricultural problems are inevitably so complex that dogmatic assertions about isolated factors lead to little but controversy and confusion. Thus, in the many discussions on the value of animal manures it is often overlooked that for most farmers the keeping of stock makes it necessary to have a considerable proportion of the farm under pasture or leys. In the absence of adequate long-range experiments on this, as on so many other fundamental problems in agriculture, it is scarcely possible to assess the relative importance of the residual effects of the leys and of the farmyard manure.

It is becoming increasingly clear that most grassland soils could be improved by being ploughed out and re-seeded, and that much arable land would benefit by longer terms under leys. Alternating grass and arable cultivation undoubtedly provides the safest means of maintaining soil fertility in humid temperate climates, but much drastic reorganisation will be needed in many branches of farming before this system can be introduced widely.

There is a growing demand for surveys of soils and methods of land utilisation on a national scale as essential preliminaries to any proposals for "planning" in agricultural production.

THE MAINTENANCE OF COCONUT GROVES.

In an article by P. M. L. Tammes in the *Bergcultures* (XII, p. 923), the data obtained from trials of a number of systems of cultivation in North Celebes is examined. Green manuring has never increased the yield of copra and is therefore only recommended when its employment is likely to effect economy in other directions. In this event a permanent and cheap cover can be formed by sowing a mixture of *Calopogonium* and *Centrosema* to which has been added a sprinkling of *Pueraria*. The most economical method is the maintenance of a pasture and grazing stock under the palms provided the latter are old enough for the lower leaves to be out of reach of the cattle. In time, it becomes a profitable side line and ensures sufficient draught being always available at harvest. The only attention required is a twice yearly cutting of the weeds not grazed down, and maintenance of the barbed wire fencing. There is, however, no evidence of increased yields attributable to this practice. The application of fertilizers has only proved profitable when there has been a deficiency in potash and phosphates and an increased yield of 10 nuts per tree has been possible. Clean weeding for a year has produced results on exhausted soil equal to those obtained from manuring. This cannot be carried out on sloping ground on account of erosion and is probably not worth while on land already in good heart. Occasional ploughing has given no crop increase. Drainage is absolutely necessary on wet low ground and no coconut plantation can be expected to succeed on such sites without it.

BRITISH WEST INDIAN ECONOMIC HISTORY IN IMPERIAL PERSPECTIVE.

By C. Y. Shephard.

(*Continued from "Tropical Agriculture", Vol. XVI, No. 7, p. 155.*)

The New Colonial Policy.

At this stage I propose to leave the West Indian scene in order to outline the development of the British Empire in other parts of the world. I shall return, later, to trace West Indian history against this background.

Up to 1763 the overseas Empire had consisted of a few fortified trading posts, islands and coast-lines. Except where rivers provided cheap means of transportation there had been no penetration into the hinterlands of the great continents. Great Britain had been interested more in trade than in the expansion of territorial sovereignty. Within a century the Empire was to expand out of all recognition, and the continental areas were to dwarf the islands in comparative importance.

In 1765 the English East India Company was granted the right of collecting taxes in Bengal, and the Company came to depend more and more upon land revenues, until it was absorbed into the great Indian Empire in 1877.

The successful revolt of the American colonies had important reactions, both immediate and ultimate, on colonial policy and development. The extension of Canada was pushed inland, to prevent American encroachment, until the Pacific barred further expansion. Botany Bay became the outlet for convicts previously sent to America, and with the subsequent influx of more reputable immigrants, grew into the great Commonwealth of Australia. Cape Colony was retained at the peace treaty of 1815, and acquired significance as an outpost protecting the route to India.

Britain was entering on that phase of development, termed the industrial revolution, which made her the workshop of the world in the nineteenth century. She was searching the world for sources of raw materials and markets. The restrictions of the old colonial system were hampering her vigorous industrial expansion. The former American colonies proved far greater customers than they had been when part of the British Empire. England was paying the West Indian planters excessive prices for their sugar, when she could have obtained it much more cheaply from foreign sources. Adam Smith had crystallized the economic thought of the industrialists by his celebrated book, "The Wealth of Nations", which extolled the virtues of free trade. No book has appeared at a more opportune time, or exercised greater influence over commercial and political policies. Britain was sick of the burden of protecting colonies which refused to contribute towards the cost of their own defence. Colonies came to be regarded as burdensome and useless and should be freed to work out their own economic and political salvation. Britain was throwing off the fetters of the old colonial system and leading the world towards free trade.

The development of the railway and steamship entirely altered the relative values of islands and continental areas. Cheap means of transportation enabled bulky commodities to be transported over long distances, and unlocked the door to the vast undeveloped resources of the great continents. Huge areas were exploited to the benefit of mankind in general, and the English manufacturers in particular. The small islands were unable to keep pace with this phenomenal development, either as suppliers of raw materials and food, or as markets for manufactured commodities. The long coastlines and numerous harbours of the West Indies, which had been a tremendous advantage in the days of small sailing ships, became a severe handicap with the advent of large steamships. The introduction of limited liability (1855) facilitated the mobilisation of enormous sums of capital for the erection of workshops, the construction of railways and steamships, and the development of new continents. Canning and cold storage enabled perishable commodities to be conveyed over great distances without deterioration.

Decline of the West Indies.

Returning now to the West Indies, we shall find that they were soon left hopelessly behind. The French pushed the development of their colonies to such an extent that St. Dominique soon produced more sugar and employed more shipping than the whole group of British Islands. The French Revolution was the signal for revolution in St. Dominique. During these internal struggles hundreds of plantations were laid waste, and the world's supply of sugar was suddenly reduced by more than a million cwt. The naval supremacy of Great Britain cut off the remaining French colonies from Europe, and by the end of the eighteenth century, sugar had risen to famine prices in London (1).

No effort was spared to take advantage of these phenomenal sugar prices. Several islands were captured, rapidly cleared and planted. Cuba had entered the lists as a sugar producer in 1789 when its ports were opened to the foreign slave trade, and within a few years its production equalled that of St. Dominique before the Revolution. By 1801, sugar production had been increased to such an extent that the market collapsed (2). Planters were urged, as they had been in 1748, to grow more food and to withdraw from the falling sugar market but the great majority of the planters were dependent upon financing houses in England to

(1) The price of sugar in Mark Lane rose from 32*s.* per cwt. in 1793 to 58*s.* in 1794 and then advanced steadily until it reached 87*s.* per cwt. in 1798. Pitman, F. W. "The Development of the British West Indies, 1700-1763", p. 9.

(2) The maximum price for 1800-1801 was 50*s.* and the minimum 28*s.* Pitman, *loc. cit.* p. 10.

which they were obliged to send their sugar. As one witness declared, the sugar planters would *probably* be ruined if they continued the production of sugar and *inevitably* if they gave it up.

During the nineteenth century the British West Indian sugar industry suffered a shattering series of blows. The slave trade was abolished in 1807. This restriction on the importation of slaves was of little consequence to the older and thickly populated islands, but proved a great handicap to the more recently acquired colonies such as Tobago, St. Lucia and British Honduras, and especially to the relatively undeveloped colonies of Trinidad and British Guiana. The restrictions of the Navigation Ordinance were gradually relaxed until in 1822, the West Indies were permitted to trade with all European ports, and with foreign countries and colonies in the New World. The great Reform Bill of 1832 dealt a death blow to the waning power of the West Indian planters in Imperial politics.

August 1st, 1834, witnessed the introduction of the apprenticeship system which was intended to prepare the slaves for the rights and responsibilities of freedom. Slave owners in the Caribbean area received compensation amounting to nearly £17 millions for 700,000 slaves. The Emancipation of the slaves in 1838 left the planters with a disorganised labour force, and doubled costs of production (1). The annual importation of British West Indian sugar into the United Kingdom fell by more than one million cwt. between 1834 and 1840. Slavery was continued in the foreign West Indies and Brazil, but the British West Indies still retained a monopoly of the English market by virtue of the prohibitive tariff levied on foreign sugar. The reduction of the British supply of sugar raised prices to an exceptionally high level and aroused a tremendous outcry in the United Kingdom, where it was contended that foreign sugar could have been purchased at half the price (1).

The West Indian planters were unable to prevent the reduction of the discriminating duty against foreign sugar in 1844 and 1845, and in 1846 the famous equalisation act was passed. This act provided for the gradual reduction of duties until in 1851-2 they would be uniform at 14*s.* per cwt. for both British and foreign sugar. Foreign slave grown sugar began to flood the British market, and prices fell precipitously (2). The West Indies were also involved in the financial crises which overtook England in 1847. The West India Bank and most of the large West Indian financing houses in England failed. Sugar estates changed hands at greatly reduced prices.

The British Government agreed to retard the reduction and extinction of the preferential duty until 1854, and made advances to the undeveloped colonies for the immigration of labourers. Reductions in wages by 40 to 50 per cent., the amalgamation of estates and improvements in

(1) The costs of producing one cwt. of muscovado sugar are said to have risen from 7*s.* 6*d.* to 16*s.* 6*d.* in Antigua and from 6*s.* to 15*s.* 6*d.* in Barbados. Costs in Cuba and Porto Rico during the latter period were estimated at 8*s.* and 8*s.* 6*d.* respectively per cwt. Beet sugar cost about 24*s.* 4*d.* per cwt. to produce. Evidence given to the Committee on Sugar and Coffee Plantations, 1848.

(1) In 1840 it was claimed that the British consumer paid 7½*d.* per lb. for the worst unrefined sugar, whilst the foreign consumer paid only 4½*d.* per lb. for much better sugar. The price of sugar in bond rose as high as 58*s.* 3*d.* per cwt. in 1840. The duty on foreign sugar was 63*s.* per cwt. Mathieson, "British Slave Emancipation, 1838-1849", p. 143.

(2) Colonial sugar fell to 29*s.* per cwt. in 1847.

Compensation to Slave Owners.

Colony.	Number of Slaves at last Registration (1832)	Average Value of a Slave from 1822 to 1830.	Relative Value of the Slaves.	Proportion of £20,000,000 to which each Colony is entitled.
		£ s. d.	£	£
Jamaica	311,692	44 15 2¼	13,951,139	6,161,927
Honduras	1,920	120 4 7½	230,844	101,958
Trinidad	22,359	105 4 5¼	2,352,655	1,039,119
Tobago	11,621	45 12 0¼	529,941	335,627
Grenada	23,556	59 6 0	1,395,784	616,444
Bahamas	9,705	29 18 9¾	290,573	128,340
Virgin Islands	5,192	31 16 1¾	165,143	72,940
British Guiana	84,915	114 11 5¾	9,729,047	4,297,117
Barbados	82,807	47 1 3½	3,897,276	1,721,345
St. Vincent	22,997	58 6 8	1,341,491	592,508
St. Lucia	13,348	56 18 7	759,890	335,627
Dominica	14,384	43 8 7½	624,715	275,923
Montserrat	6,355	36 17 10¾	234,466	103,558
Antigua	29,537	32 12 10½	964,198	425,866
St. Christopher	20,660	36 6 10¼	756,840	331,630
Nevis	8,722	39 3 11¾	341,893	151,007
Bermuda	4,203	27 4 11¾	114,527	50,584

factory machinery enabled the planters to reduce their costs of production, while the rapid increase in world demand restored prices to a moderately profitable level.

The tremendous expansion of the European beet sugar industry soon brought a most formidable and threatening competitor into the field. Prohibitive import duties assured producers of beet sugar of a profitable domestic market, and export bounties enabled them to undersell cane sugar (1). Between 1881 and 1896 the price of sugar fell by 50 per cent. (2). In less than ten years (1882 to 1891), imports of cane sugar into the United Kingdom from the British West Indies and British Guiana fell from 200,000 to 50,000 tons per annum. During the same period imports of beet sugar jumped from 400,000 tons to more than 1,000,000 tons (3). The United States of America replaced the United Kingdom as the principal market for British West Indian sugar when she imposed a duty, equal in amount to the export bounty, on European beet sugar (4).

The smaller West Indian estates were bought at bankrupt prices and amalgamated into larger units by optimistic investors. Hundreds of thousands of pounds were spent in the erection of central factories which reduced costs of manufacture by 50 per cent. (5). But the troubles of the planters were by no means at an end. A serious cane disease broke out about 1890 and spread with amazing rapidity throughout the islands. Losses in cane estimated at between 25 and 50 per cent. threatened the very existence of the industry which accounted for 84 per cent. of the total exports (6).

Change in British Colonial Policy.

Events in other parts of the world were meanwhile causing Great Britain to change her attitude towards the colonial problem. The opening of the Suez Canal in 1869 transformed the Mediterranean from a backwater into the highway of commerce to the Far East. Countries bordering the Mediterranean and Red Sea acquired a new significance in Imperial policy. Germany emerged from her war with France in 1870 as the greatest military power in Europe. Rapid industrialisation soon brought her into competition with the United Kingdom for supplies of raw materials and markets. The acquisition of colonies became part of her economic and political programme. France, sore at the loss of Alsace-Lorraine, and grieved by her declining man power, sought consolation and redress in Indo-China, Madagascar and North and West Africa. Russia, baulked from obtaining Constantinople in 1878, spread more energetically into Siberia and Central Asia, thereby constituting a threat to India.

England, the greatest of all industrial powers, was faced with the alternative of witnessing her exclusion from Africa and the Pacific, or of joining in the scramble. She joined in the scramble. Having acquired additional colonies primarily to preserve the open door, she assumed towards them a benevolent attitude which was in marked contrast to the old colonial system. The colonies were to be regarded as undeveloped estates, held in trust for the benefit of civilisation in general, and the inhabitants of the colonies in particular. The advent of Mr. Joseph Chamberlain to the Colonial Office in 1895 heralded this new orientation of Colonial policy.

We left the British West Indies in 1896 on the verge of collapse. The West India Royal Commission of 1897 urged the abolition of the export bounties on beet sugar as the most effective means of assisting the West Indian sugar industry. The abolition of the bounty system was secured by the Brussels Convention of 1902, which came into effect on 1st September, 1903. The Imperial Government granted £250,000 to enable the West Indian sugar producers to tide over the intervening period. Barbados devoted her £80,000 to the formation of her successful Sugar Industry Bank, but elsewhere the gift was distributed, as was intended, among the individual sugar producers.

The Imperial Department of Agriculture for the West Indies was formed at Imperial expense and concentrated its efforts on the re-organisation of the sugar industry, and the development or introduction of alternative and subsidiary crops. One of its greatest achievements was the erection of the central sugar factory in Antigua, which was followed by the complete centralisation of sugar manufacture in St. Kitts(1). Seedling canes rapidly replaced the disease-susceptible Bourbon variety. The configuration of some of the smaller islands precluded large factories, and they gradually passed from a dependence on sugar to limes, cotton, arrowroot, cacao, nutmegs and a variety of other crops (2). Bananas in Jamaica

(1) Germany alone paid more than £70,000,000 in export bounties between 1840 and 1903.

(2) Unrefined sugar realised 21*s.* 8½*d.* per cwt. in the United Kingdom during 1881 and only 10*s.* 10*d.* in 1896. West India Royal Commission Report. App. C. pt. 1. p. 196.

(3) W.I.R.C. App. C. Pt. 1. p. 195.

(4) By the Dingley Tariff Bill of 1897.

(5) The Colonial Co., for example, spent £339,000 between 1870 and 1895 in modernising its factory and transport equipment. British Guiana imported sugar machinery to the value of £1,307,500 between 1880 and 1895. The number of sugar factories was reduced in Trinidad from 88 in 1889 to 39 in 1896; and in British Guiana from 180 in 1849 to 64 in 1896. Costs of manufacturing sugar fell in British Guiana from £9 15*s.* per ton in 1883-4 to £4 15*s.* in 1895-6 and in Trinidad from £8 9*s.* in 1883 to £3 11*s.* in 1896. W.I.R.C.

(6) In 1882 sugar contributed £6,884,000 to the total exports of £8,224,000 from the British West Indies and British Guiana. In 1896 exports were valued at £6,106,000 of which sugar represented £3,251,000. W.I.R.C. Report. App. B, p. 157.

(1) Gunthorpe's Central Factory, Antigua, commenced manufacturing in 1905, and the St. Kitts (Basseterre) Factory in 1912.

(2) In Dominica, Montserrat, Tortola, Nevis, Grenada and Tobago, sugar production once the staple industry, is now negligible. In Antigua, St. Kitts and Barbados sugar remains the only crop of importance.

and cacao in Trinidad replaced sugar as the most important industry. With this growing diversification of products the British West Indies lost that superficial air of unity which sugar had conferred upon them.

The sugar industry was soon faced with competition from a new quarter. The Reciprocity Treaty between the U.S.A. and Cuba gave the island a monopoly of that portion of the American sugar market not catered for by her internal and insular production. American capital poured into Cuba, and the British West Indies found themselves not only completely excluded from the U.S.A. market, but also faced with increasing competition in the unprotected market of the United Kingdom (1). Supplies of British West Indian sugar were diverted to Canada which had afforded a preferential duty since 1898 (2).

Consequences of the Great War.

The Great War dislocated the European beet sugar industry and brought great but fleeting prosperity to producers of cane sugar. The revival of the beet industry after the war, coupled with the inflated cane industry, caused the price of sugar in the open market to fall below the cost of production. The United Kingdom, had, in the meantime withdrawn from the Brussels Convention, and was free, in 1919, to give a preference to British sugar. This preference has been the salvation of the British West Indian sugar industry, but has not prevented prices from falling to a desperately low level.

Since the war the nations of the world, and especially those of Europe, have been obsessed with fears as to their security. Each country has sought to reduce its dependence on other countries for supplies of essential raw materials and food. International trade is dwindling. Political considerations play a more important part than economic factors in determining the location and profitableness of some industries. The production of armaments is becoming the prime function of civilisation.

The United Kingdom, mindful of the straits to which she was reduced during the war by the German submarine campaign, has endeavoured to resuscitate agriculture by the development of a beet-sugar industry. Subsidies have been granted to growers of sugar-beet and manufacturers of beet-sugar at rates far in excess of those given by any European power. Few West Indian colonies have any industry other than agriculture and they cannot subsidise one industry at the expense of another for any appreciable period of time. Sugar, their principal crop, has ever been the plaything of politicians and although the British West Indies rank with the cheapest producers of sugar in the world they remain among the least prosperous. Sugar producers with the highest costs of production are the most prosperous. Had the British West Indies received assistance at the same initial rate as the beet-sugar industry in the United Kingdom they could have given away their sugar and still have declared dividends approaching 100 per cent. per annum.

Costs of sugar production in the British West Indies have been revolutionised during the past fifteen years. The introduction of cost accounting, mechanical tillage, scientific cultivation, better varieties of cane, improved machinery and technical control in the factory, have effected astonishing reductions in costs. If all subsidies, bounties, discriminating tariffs and other political interferences were swept away, the British West Indian sugar industry would enter upon an era of comfortable prosperity. The beet-sugar industry would disappear. Cane production would cease in Australia, South Africa and Hawaii; and the British Colonies together with Java, Cuba, India and a few others would supply the sugar requirements of the world with profit to themselves and advantage to the consumers.

(1) In 1899-1900 Cuban sugar exports were 345,568 short tons. Following the Reciprocity Treaty of 1903, exports rose to 2,719,961 tons in 1912-13 and to 5,125,970 tons in 1924-5.

(2) The preference was originally 25 per cent. of the raw sugar duty. There have since been many changes on a reciprocal basis.

Bibliography.

Beer, G. L.—The Old Colonial System. Part I in two volumes. *Macmillan*, 1912.

Beer, G. L.—British Colonial Policy, 1754-1765. *Macmillan*, 1922.

Beer, G. L.—The Origins of the British Colonial Systems 1578-1660. *Macmillan*, 1922.

Daniel, E. W.—West Indian Histories. Book III, *Nelson*.

Knowles, L. C. A.—The Economic Development of the British Overseas Empire. *Routledge*, 1924.

Mathieson, W. L.—British Slavery and its Abolition 1823-1838. *Longmans Green*, 1926.

Mathieson, W. L.—British Slave Emancipation 1838-1849. *Longmans Green*, 1932.

Mun, Thomas.—England's Treasure by Forraign Trade, 1664. Reprinted *Macmillan*, 1895.

Newton, A. P.—The European Nations in the West Indies, 1493-1688. *Black*, 1933.

Pitman, F. W.—The Development of the British West Indies 1700-1763. *Yale University Press*, 1917.

Shephard, C. Y.—The Sugar Industry of the British West Indies and British Guiana with special reference to Trinidad. *Economic Geography*, V, No. 2, 1929.

West India Royal Commission, C. 8655, 1897.

BANANA LEAF SPOT CONTROL.

Banana leaf spot (*Cercospora Musae*) was almost completely controlled in New South Wales by the application of five sprays of Bordeaux mixture at monthly intervals during the summer. Even the application of two sprays at intervals of one or two months gave a considerable degree of control. Promising results have been obtained by the use of copper sulphate dust, five applications of dust being equal in results to two Bordeaux sprayings. —(C. J. Magie in *Agric. Jr. New South Wales*, Vol. 49, pp. 662-4.)

THE MAXIMUM YIELD OF CACAO.

A Discussion of Some Factors that Contribute to High Production.

By F. Hardy.

I. Introductory.

Plant physiologists have long been interested to discover the magnitude of the *absolute maximum production* of different crop plants raised under the best growth conditions. Mathematical calculations, based on established growth laws, have been invoked to prove that, in most cases, yields approximating to the maximum have not yet been realised or even approached by practical plant growers, and the reasons for this failure are being diligently sought. Thus, in a recent article on agrobiology (1), Willcox has discussed the application of the famous Mitscherlich equation to the assessment of maximum yields of wheat, cotton and potatoes, and has concluded that the highest yields so far obtained are still only about three-quarters of the theoretical maxima, despite the many genetic and agricultural improvements that have been effected during many years of research. In the case of maize, the theoretical maximum yield (of 225 bushels per acre) has apparently been attained in certain parts of the Great Corn Belt of the United States, and it has also been approached in the case of sugar-cane in Hawaii, where the record yield is over 110 tons of plant canes per acre. The theoretical maximum for sugar-cane containing 0.084 per cent. of nitrogen is about 160 tons per acre for the new P.O.J. varieties, on the basis of the Mitscherlich equation.

Recent developments in the chemiculture of plants, based on the researches of Gericke in California, by which plants are grown in suitably aerated saline water-cultures, have demonstrated that even larger crops than those produced under the best field conditions may be obtained with plants such as wheat, maize, potatoes, tomatoes, legumes and various other vegetables and flowers. Thus, yields of 66 tons of potatoes and 120 to 217 tons of tomatoes per acre of space have been claimed for these artificially-controlled "hydroponic" methods (2).

Maximum Production of Cacao.

An attempt to calculate the theoretical maximum yield of dry cacao-bean per acre of land, by applying the Mitscherlich equation for nitrogen utilisation gives a value of something over 1,500 lb. dry cacao per acre. This result is based on three assumptions*, namely, (i) that the maximum quantity of nitrogen which can be usefully absorbed during one growth cycle by any species of plant growing on one acre of soil, according to the Mitscherlich equation, is 318 lb., (ii) that the average content of nitrogen in cacao leaves, twigs and fruits is 2.1 per cent. of the oven-dry weight, and (iii) that the ratio of the weight of beans to the weight of shoots produced annually is 1 to 10.

It should be stressed, however, that this theoretical value for cacao is only an approximation and the calculation may not strictly apply to arboraceous crops. Nevertheless, the derived quantity provides an indication of the order of magnitude of yield of cacao that should be attainable under good growth conditions. Comparison of this theoretical maximum yield (1,500 lb. of dry cacao-bean per acre of land) with published data of actual cacao yields compiled by Voelcker (3) shows that, at least under climatic conditions obtaining in parts of West Africa, the productivity of cacao soils may reach a high level. Thus, yields ranging from 800 to 1,200 lb. per acre for experiment station plots in Nigeria and the Gold Coast have been recorded. The average yield for Trinidad cacao fields of age less than 25 years, however, is very much less, namely, only 366 lb. (2.2 bags) per acre [according to Shephard (4)]. "Good" cacao fields in Trinidad and Tobago seldom produce more than 600 lb. (3.6 bags) of dry bean per acre, although occasionally yields above 850 lb. (5.1 bags) per acre have been reported for the best types of soil.*

An example of an exceptionally high cacao yield has been reported in St. Lucia, B.W.I.,† for a 27-year old 42-acre field, planted 280 trees to the acre, which has given an average yield of 1,545 lb. (9.4 bags) of dry cacao per acre over a period of four years, the yield in one year actually exceeding 1,880 lb. per acre.

It thus seems likely that a maximum production of around 2,000 *lb.* (12 *bags*) *per acre* for cacao is not outside the range of possibility under ideal conditions, although the chances of the yielding capacity of cacao soils in Trinidad and Tobago attaining values much greater than this, even if planted with Imperial College Selection (I.C.S.) trees, would appear rather remote, on the grounds that the selected trees might not maintain their high rate of production when planted in blocks under estate conditions. Furthermore, in any field of cacao, some trees will suffer damage, and for this and other reasons, may fail to provide their proper share of the yield.

* *Note.*— (i) Value quoted by Willcox (1).
(ii) Chemical analyses by G. Rodriguez.
(iii) Value derived from analyses by Marcano, quoted by J. B. Harrison ("Rocks and Soils of Grenada", 1896, pp. 30-8).

* In one of Dr. Pound's manurial experiment plots at Roxborough, Tobago, a yield of 2,088 lb. of dry cacao per acre was recorded for the 1937-38 crop.

† C. Y. Shephard, private communication. *Individual* selected trees in Nigeria have been reported by Voelcker (17) to have yielded at rates approaching 7,000 lb. (42 bags) of dry cacao per acre, but such records are meaningless unless they refer to *average* yields of groups of trees occupying considerable areas of land.

Limiting Ecological Factors.

From this discussion, the following questions naturally arise: (i) *What factor or factors are limiting the productivity of existing cacao lands* in any particular area? (ii) What modifications in planting technique and cultivation practices would be required to increase production? (iii) Which of the recommended modifications would be profitable under existing economic conditions?

In order to answer these questions, the relative importance of the fundamental factors that decide the yield of cacao trees growing under estate conditions must be accurately assessed, and it is the main object of the ecological investigator to identify and to measure the contributions made by these factors to the ultimate yield of cacao per unit area of land. The following sections are accordingly devoted to a consideration of some of the factors, and to an attempt to identify those that may be limiting production, for example, in the cacao fields of Trinidad, for which we have the most information.

II. Factors Controlling Productivity in Cacao.

The productivity of the trees comprising a cacao field is controlled both by genetic (internal) and by environmental (external) factors. Among the *genetic factors* may be included:—

(i) Density of flower production.
(ii) Time and periodicity of flower formation.
(iii) Degree of compatibility of reproductive organs of the flowers.
(iv) Proportion of fruits that set and ripen.
(v) Number of beans in an average ripe pod.
(vi) Average weight of individual beans.
(vii) Average age of trees.

Among the *environmental factors* may be included:—

(i) Soil conditions (supply of available water, air and nutrients; soil temperature; harmful factors).
(ii) Atmospheric (climatic) conditions (humidity, light, air-movement, air-temperature).
(iii) Incidence—density and efficiency of pollinating agents.
(iv) Distribution of compatible and incompatible trees.
(v) Incidence of pests and diseases; damage by falling shade trees, &c.
(vi) Density of tree population (planting distance), deciding "competition" and root-room, especially in old fields.

Many of these factors are closely inter-related. Thus, the production of flowers is believed to be largely controlled by environmental conditions such as the supply of nutrients and water, and the setting of fruits may partly depend on the efficiency of fertilisation. In practically every case, however, the efficacy of genetic factors (except perhaps pollen compatibility) *is modifiable to a greater or lesser extent by environmental conditions.* Furthermore, even the process of pollination depends on the simultaneous presence of receptive flowers and of suitable agents of pollination, which strictly speaking is itself an environmental circumstance.

Several of the above-mentioned aspects of cacao productiveness have been studied under the Imperial College Cacao Research Scheme, and many relevant results have been published in previous Annual Reports, both by the Botanical and by the Chemical Officers. Nevertheless, much further information is needed concerning the significance and relative importance of the various factors, notably those concerned in plant and soil interactions.

Before considering possible lines of further work, a summary of some results already obtained, and of suggestions put forward for additional research, might be helpful.

III. Previous Physiological Results.

In discussing the contributions which botanical researches have made to the problem of increasing cacao production, Cheesman (6) has stressed the operation of the three variables in the equation:— *Cocoa per acre* equals *cocoa per pod* × *pods per tree* × *trees per acre.*

With regard to the second variable (pods per tree), he considers that, even though "much of the "variation from tree to tree on the average estate "springs from causes other than botanical ones, "... there remains a proportion that can only "be ascribed to the constitution of the trees" (*ibid.* p. 123). In connection with the first variable (cocoa per pod), Cheesman has indicated that, although one pound of dry cacao in Trinidad requires on the average 12 pods to produce it, some trees regularly produce it in 6 or 7 pods. He attributes this difference mainly to genetic variation between the trees, but he concedes that external environmental factors may also play a part in determining the actual weight of cacao bean in a pod, so that "after (seasonal or environ-"mental) variations have been allowed for by "taking averages of large samples, ... differences "between trees* still remain" (*ibid.* p. 124).

Further, Cheesman states that "some types of "cacao suffer more than others from deficiencies "in their environment" (*ibid.* p. 125). Thus, if the producing capacity of certain types of cacao is inherently very high, one type may yet exhibit better performance than another, even when environmental conditions are unsuitable. The difficulty is to unravel the contributing causes, both of producing capacity and field performance, and this analysis can only be accomplished by a thorough study of the genetics, physiology and ecology of the cacao tree as it grows in the field.

In order to produce ripe pods, the reproductive organs of the cacao tree must survive a series of vicissitudes, including severe competition between individual reproductive organs on the same tree (or even on the same branch), and between those on neighbouring trees, as well as the depredations of pests and diseases. At several stages in their life history, cacao pods are liable to be lost, commencing with flower formation and development, through pollination and fertilisation, and

* A striking instance of this is the great variation in thickness of pod wall.

ending with the setting and growth of the fruit and the maturation of the seeds. Detailed observations of the facts of survival are the first need in any experimental programme designed to assess the factors contributing to final success. In practice, it has so far been found inexpedient to study the individual factors separately, because of their close inter-relationships. Much attention has already been paid to the general question of *fruit setting*.

The Setting of Cacao Fruits.

Preliminary observations recorded by Pyke (7) over a period of 1½ years' duration for two plots of mature cacao trees situated in different valleys* of the Northern Range of Trinidad, demonstrated that a marked yearly fruit-setting cycle occurred, having a main period during July to September, and a smaller one during December. In the dry season (February to June), practically no fruits were set, and very few were set during November. Some trees appeared to be continuous setters and some sporadic setters, the former ultimately producing the greater number of ripe pods. Setting seemed to show some correspondence with previous flowering, except that a particular period of abundant flowering during the early part of the rainy season (late May to July)—the so-called "crazy flowering"—was *not* accompanied by subsequent setting. During the time of maximum setting (July to September), a flush of new foliage appeared, and this was associated with a temporary reduction in the amount of setting.

Other intermittent observations recorded by Pound (8) for plots of young trees at River Estate, Trinidad, supplement those by Pyke, though they revealed interesting differences. Here again, setting showed a pronounced peak in the latter half of the year, but the correlation between the number of flowers produced and the number of fruits set during the subsequent week proved *not* to be statistically significant. Pound therefore drew the interesting conclusions (*ibid.* p. 31): (*a*) that "setting bears little relation to the "number of flowers on the tree"; (*b*) that "the inter-relations of rainfall, flush, flowering "and setting in the cacao tree under Trinidad "conditions are exceedingly complex, and no one "factor or simple set of factors can be held to "govern setting"; (*c*) that "from the middle of "July onwards, some factors independent of those "governing flush confer increased *potentiality* for "setting on the flowers of the cacao tree", and this potentiality "may be regarded as requiring "other factors, probably nutritional, for its "realisation", and (*d*) that actual setting may therefore "tend to be inhibited by flush, because "the young leaves compete with the flowers for nutrients". Among the nutrients concerned in the setting-potentiality of cacao flowers, Pound particularly stressed carbohydrates and nitrogen. He attempted to test their significance by ringing, pruning and manuring experiments. The results obtained showed (i) that the augmentation of the carbohydrate content of a branch (by ringing) greatly increased the total number of flowers produced per unit length of branch, but it did not increase the proportionate number of flowers that set fruits; (ii) that the reduction of carbohydrate (by pruning) greatly reduced the number of fruits that set, and (iii) that an increase in nitrogen content (by manuring with nitrate of soda) apparently greatly increased the number of fruits that set. It was therefore concluded that the *actual levels* in the supplies of carbohydrate and nitrogen are more important in fruit-setting than their relative amounts (carbohydrate-nitrogen ratio), at least under the conditions of these experiments, but the investigation needs to be repeated during the early months of a year, and on a much more comprehensive scale. As Voelcker (17) puts it "although this manipulation caused a great increase in flowering and setting, the *percentage* of setting remained substantially the same."

The close relationship between fruit-setting and environmental conditions is further revealed by independent observations made by McDonald in his detailed studies during 1931 to 1934 of cacao trees growing in two contrasted "good" and "bad" plots (9). These observations demonstrated that "the chief period of flowering, "setting and development of young fruits occurs "during a period of high moisture conditions", in the soil and the atmosphere, which extends uniformly over about three months of the year in Trinidad. Leaf flushing, induced by dry spells occurring within the moist period, was followed by a temporary check in flowering and fruit setting. An important difference between the two plots was revealed in the much smaller and less extreme fluctuations in the moisture status of the soil and the atmosphere of the "good" plot. The greater the fluctuations in the moisture environment, the more irregular were the manifestations of vegetative and reproductive activities in the tree.*

The detailed records of Pyke, Pound and McDonald, demonstrate that the cacao tree is usually unable to support simultaneously a strong flush of foliage and an abundant burst of flowering and fruiting. Very definite relationships were noted by McDonald between environmental moisture conditions and the behaviour of the cacao tree, but, how far moisture conditions are linked with the internal nutrition of the tree, in its effect on the development of flowers and fruits, has not yet been specifically investigated.

Botanical observations have established the fact that cacao flowers not pollinated generally fall within three days after opening. Nevertheless, pollination may not necessarily cause fertilisation

* River Estate, Diego Martin Valley, 10 miles west of Port-of-Spain, and Caura Valley, 12 miles east of Port-of-Spain.

* On one occasion in late November, the temporary coincidence of a drying soil with a highly humid atmosphere was accompanied in each plot by a severe attack of thrips, presumably favoured by a sudden reduction of leaf moisture.

and setting; it can do so only when the pollen is *compatible*. The cacao tree population of Trinidad consists both of self-compatible and self-incompatible trees, the relative number of the latter being unexpectedly large in comparison with Nigeria where the trees are practically all self-compatible (3). At first it was believed that incompatibility was merely a temporary state (10), (8), and that it could be changed to compatibility by a suitable alteration of the environment, for example, improved mineral nutrition of the tree (11). The recent work of Voelcker (3), (16) has thrown considerable doubt on this supposition; consequently incompatibility has been urged as one of the main reasons why many cacao trees seldom set much fruit, and why the yields of cacao in Trinidad are so much smaller than in West Africa. In a field where most of the trees are self-incompatible, adequate fertilisation and pod-production can only occur if pollen is produced in sufficient quantity by the flowers of the minority of self-compatible trees. Nor can it occur if there is a shortage in the number of suitable agents of pollination, and this may depend primarily on environmental conditions. For these and other reasons, Voelcker (16) presumes that a dearth of pollinating agents, together with a high proportion of self-incompatible trees, might adversely affect final cacao yields, but he admits that factual proof of this most important conclusion, based on data collected over a long period of time, is not yet forthcoming. Evidently, there is here an urgent need of a special entomological investigation into the ecology of the pollinating agents of cacao flowers, and into possible means of increasing and maintaining their population in the cacao fields of Trinidad. Voelcker's suggestion that periodic bursts of pod-setting in Trinidad may be correlated with the incidence of agents of pollination certainly warrants experimental study.

The Shedding of Cacao Fruits.

Apart from the question of pod-setting, most observers are agreed that wilting, shrivelling and shedding of young cacao pods that have properly set are common causes of low yields.* Thus, many planters in Trinidad maintain that a *deficiency in the number of pods that appear to have set is seldom the cause of low production in the cacao fields*, and that, *were it not for the apparent inability of the tree to hold its young fruits, yields would be very much greater*.

The physiological significance of fruit-shedding has received considerable attention by botanists, particularly in the case of cotton. In cotton, the whole period from flowering to boll opening is about 56 days, and shedding is most common about 8 days after flowering. The time of the first cell division of the fertilised ovum is 4 days after the flower has opened, and therefore about 4 days before the completion of abscission. A critical stage of relatively slow development precedes the marked augmentation of growth consequent on fertilisation, and it has been suggested by Mason (12) that interruption in the supply of organic nutrients during this critical stage is the main cause of abscission. In cacao, the duration from flowering to pod-ripening is about 150 days, and the time of the first division of the ovum, according to Cheesman (13), is about 50 days after fertilization has occurred, at which stage the young pod is some 4 to 5 cm. long. Shedding in cacao often occurs when the size of the pods has attained this dimension,* and is usually preceded by marked cessation of growth, a paling of the green colour, and subsequent blackening and shrivelling. If the supply of water and organic and mineral nutrients is inadequate at the period of initiation of embryo growth, further development may be interrupted, and abortion, abscission and shedding may follow (14).

The possible significance and the exact mechanism of these processes in the case of cacao have not yet been elucidated, nor have the specific effects of environment factors, on shedding been exhaustively investigated. It is important to note, however, that Voelcker's recent results (15) suggest that the significance of the presumed "50-day critical stage" (coincident with cell division in the fertilised ovum), may have been overstressed. Voelcker pollinated by hand a number of cacao flowers daily throughout the year, both in Nigeria and in Trinidad, and noted the time interval between fertilization and wilting. The data thus obtained showed no greater wilting at the 50-day interval than at any other period, so that "the cause of wilt is to be sought in the "physiological state of the tree itself", and not in the 50-day-old fruit whose embryo is commencing cell-division (15). After the losses caused by unsuccessful pollination have ceased, subsequent shedding is probably determined mainly by the operation of seasonal environmental factors.

It is thus evident that the solution of the problem of fruit-shedding in cacao would necessitate a thorough physiological study of the absorption, transportation, storage and utilisation of mineral nutrients and water, and of the elaboration and redistribution of synthesised organic compounds by the different parts of the cacao tree concerned in these processes. As regards the water and mineral nutrient relationships of cacao and their bearing on productivity, some evidence of the part played by the soil may

* Pyke (7) found great variation in the losses caused by fruit-shedding in Trinidad; some trees lost 92.5 per cent. of their pods, others only 19 per cent., the average being 69 per cent.

* The observations of Hewison and Ababio (*Gold Coast Year Book*; 1929, pp. 87-94), showed that shedding of young pods occurred over a wide range of age, but was greatest during the first seven days, during which, 30 per cent. of the total losses occurred. A second period of loss occurred when the fruits were 20 to 30 days old, and continued to 40 to 50 days. Further losses were rare after 60 days had elapsed.

next be considered, since soil treatment is one of the easiest and most direct methods employed by crop growers for improving the environmental conditions.

IV. Nutrient Relationships of Cacao.

Growth Factors of Cacao Soils.

The productive capacity of a soil for cacao depends on many factors, chief among which are its ability to provide sufficient water, nutrients and oxygen to the root-system and the absence of certain injurious substances. Any one of these factors may limit the growth of the tree if not present in adequate amount. In order to determine which growth factors limit production, the simplest procedure is the comparative method, involving periodic measurements of as many factors as possible, within two contrasted plots or pairs of plots, one of which regularly produces satisfactory crops (the "good" plot), and the other, unsatisfactory crops (the "bad" plot). The factors which are customarily measured are both "static" factors, which do not appreciably fluctuate (for example, soil texture, soil acidity, total organic matter and nitrogen, and potential plant nutrients) and "dynamic" factors whose magnitude varies greatly as the seasons progress (for example, available soil moisture and available nutrients). This is the method that was applied in the ecological investigations of cacao carried out in Trinidad during the period January, 1931 to December, 1933; and fully described by J. A. McDonald in the first three Annual Reports on Cacao Research.

The Nutrient Supply of Cacao Soils.

Among other results, the importance of *nutrient supply* in cacao-growing soils was established, and it was found that the "bad" plot particularly was lacking available phosphate. The chemical examination of other cacao soils, undertaken during this period in connection with soil surveys, further demonstrated that a shortage of available phosphate is a common feature of most West Indian cacao clay soils and red volcanic soils, while shortage of available potash is characteristic of many of the sandy soils.* Nearly all the soils, however, are adequately supplied with nitrogen.

* A detailed summary of the results obtained is presented in the Introductory to the Chemical Section of the Fifth Annual Report, pages 25 to 28.

Table I.

Effects of Manuring on Cacao Yields of Trinidad Soils of Different Nutrient Status (1936-37).

Code No.	Designation of Experiment.	Yields (lb. ac.) Initl.	Yields (lb. ac.) Final.	Per cent. Increase. (%)	Index of Texture. (I.T.)	Reaction. (pH)	Total Organic Matter. (%)	Total Nitrogen. (%)	Avail. Phosphate P_2O_5 (p.p.m.)	Avail. Potash K_2O (p.p.m.)	Effective Manure.
(1) Acidic Alluvial Clays; River Vegas of Northern Plain, Trinidad.											
A 2	Las H. I ...	250	433	73	47	6.2	4.0	0.27	29	139	P
A 3	Las H. II ...	196	343	75	—	—	—	—	—	—	PK
A 4	Las H. III ...	263	392	49	—	—	—	—	—	—	P
(2) Calcareous Black Clay; Princes Town-Rio Claro District, Trinidad.											
A 5	Rio C. III ...	346	603	74	62	7.1	6.0	0.35	35	154	P
A 7	Rio C. IV ...	300	405	35	61	6.7	8.7	0.47	30	175	P
Limits of Adequacy (Clays)		—	—	—	55	—	4.0	0.25	50	175	
(3) Acidic Alluvial Sands and Silts; River Vegas of Northern Range, Trinidad.											
	Torrecilla ...	548	756	38	23	6.7	2.4	0.16	21	150	P
A 12	River II ...	841	1269	51	18	6.6	2.6	0.14	52	64	NP_2K
A 11	River III ...	909	1280	41	18	6.2	1.4	0.13	19	37	NP_2K
A 13	River IV ...	513	708	38	25	6.1	2.7	0.16	21	84	PK
A 14	River V ...	510	1115	119	35	6.0	3.2	0.19	15	56	PK
A 8	River VII ...	600	1008	68	26	6.4	2.0	0.15	11	39	K
A 10	River IX ...	703	953	36	25	5.5	1.6	0.13	14	52	K+mulch
A 18	River X ...	540	760	41	20	4.9	2.1	0.12	16	39	K+mulch
A 19	River XI ...	473	700	48	20	5.7	1.8	0.13	22	79	Pen manure
A 20	River XII ...	537	781	45	17	5.7	1.7	0.13	58	104	PK, mulch
Means (River Estate) ...		625	953	52	23	5.9	2.1	0.14	25	62	
Limits of Adequacy (Sands)		—	—	—	(25)	—	3.0	0.20	30	100	
(4) Neutral Loams, mostly Alluvial, Tobago.											
A 23	King's Bay ...	850	1190	40	—	—	—	—	—	—	PK
A 24	Richmond ...	590	714	21	—	—	—	—	—	—	K
A 22	Roxboro' ...	925	1156	25	—	—	—	—	—	—	K

Table II.

RELATIONSHIP BETWEEN NUTRIENT STATUS AND YIELDING CAPACITY OF CACAO SOILS.
(Comparison between West Indian Areas and Gold Coast Colony.)

Soil-Type.	Av. Yield Dry Cacao lb./ac.	Texture, Reaction, Organic Status.				Nutrient Status.			Chief Nutrient Deficiency.
							Available		
		I.T.	pH	Org. Matter %	C/N Ratio	Total N %	P_2O_5 p.p.m.	K_2O p.p.m.	
(I) TRINIDAD.									
(A) CENTRAL RANGE (MONTSERRAT DISTRICT).									
(1) Chocolate Soil ...	650	43	7.2	6.0	9.6	0.34	343	309	Nil
(2) Brasso Sand (Good) ...	490	22	6.6	3.3	8.4	0.25	53	455	P (?)
(3) Brasso Sand (Poor) ...	250	14	5.7	1.7	7.2	0.14	24	79	**N, P, K**
(4) Alluvial Soil ...	490	20	6.1	2.5	9.0	0.16	25	91	**N, P, K**
(5) Brasso Clay (Good) ...	440	37	6.9	4.4	9.7	0.28	71	145	P (?), K (?)
(6) Brasso Clay (Bad) ...	140	40	6.6	3.9	7.7	0.28	71	151	P (?), K (?) (Gypsum)
(7) Charuma Clay ...	240	44	5.5	5.1	8.6	0.30	29	112	**P**, K (?)
Average —Good ...	(550)	40	6.9	5.3	9.4	0.33	149	254	Nil
—Bad ...	(240)	32	5.8	3.3	7.8	0.24	32	119	N (?) **P**, **K** (?)
(B) NORTHERN PLAIN.									
(1) Acidic Alluv. Clays ...	230	35	5.3	3.1	8.3	0.21	29	96	**P**, K (?)
(2) Sangre Grande Clay ...	250	40	4.9	3.3	8.5	0.22	18	81	**P**, K (?)
(C) NORTHERN RANGE.									
(1) Acidic Alluv. Sand ...	500	19	5.8	1.9	8.3	0.14	21	64	N, P, **K**
(D) SOUTHERN PLAIN.									
(1) Princes Town Marl ...	475	62	6.6	6.1	9.7	0.35	17	227	**P**
(2) Moruga Sand Soil ...	350	17	5.8	3.2	10.5	0.13	19	138	**N**, **P**, K (?)
PROVISIONAL STANDARDS :—TRINIDAD CACAO SOILS. Lower Limits of Adequacy.									
Sandy Soils		(10)	5.8	3.0	8.5	0.20	30	100	
Clay Soils		(36)	6.0	4.0	9.5	0.25	50	175	
(II) TOBAGO.									
(1) Schist Soil	450	35	6.7	4.8	10.2	0.28	82	87	**K**
(2) Diorite Soil	650	39	6.4	4.7	10.2	0.26	30	94	P (?), **K**
(3) Alluvial Soil ...	650	29	6.5	4.1	12.0	0.20	75	80	N (?), **K**
(III) GRENADA.									
(1) Andesite Red Soil ...	600	40	6.9	3.7	10.7	0.20	85	380	Nil
(IV) GOLD COAST.									
Good	700	10	6.9	3.4	11.7	0.18	41	163	N (?)
Medium	700	9	6.0	2.1	10.5	0.12	20	75	N, P, K
Bad	480	7	5.7	1.4	9.2	0.09	18	58	**N**, **P**, **K**

The discovery of a very unsatisfactory nutrient status in cacao soils immediately led to the inauguration of manurial field experiments, whose number has been rapidly multiplied since 1932, especially in Trinidad.* The responses to manures obtained in some of these field trials are given in Table I ; they concern three important Trinidadian soil-types, namely, (i) acidic clays forming alluvial strips bordering the northern tributary-rivers of the Caroni and the Oropouche basin, (ii) black clays derived from marl occurring in the southern Rio Claro District, and (iii) alluvial sands and silts occurring at River Estate, situated in a broad valley within the Northern Range, west of Port-of-Spain. The natural yields of the unmanured plot soils, as given in the first column of Table I, are 240 lb. dry cacao per acre for the first soil-type, 325 lb. for the second, and 625 lb. for the third.

* These manurial experiments are fully described in the Annual Reports on Cacao Research for 1933 onwards.

In each case, it will be noted that the yield of the unmanured soil is relatively very low, compared with the 2,000 lb. per acre standard provisionally accepted as the maximum attainable yield. The *production deficits* for the three soil-types are approximately 88 per cent., 84 per cent. and 69 per cent. respectively. The highest yields so far obtained by manuring these soils are also stated in Table I. Although the figures show considerable increases over the natural yields of the unmanured soils, namely, about 70, 55 and 52 per cent. respectively, the final yields obtained by the most suitable manurial treatments still fall far short of the theoretical maximum, the new production deficits being 80, 75 and 52 per cent., which are still very large. The close relationship between the kinds of manurial response and the chemical composition of the soils as gauged by chemical tests is clearly revealed by the laboratory data in Table I.

In Table II are shown the approximate natural yields and chemical status of other important soil-types occurring in Trinidad, Tobago and Grenada, and some occurring in the Gold Coast Colony. It should be noted that the yields given in these two tables are values selected somewhat at random from the data from soil surveys or for plots of manurial experiments;* they do not refer particularly to any one year, though most were recorded in the 1936-37 season. They serve merely to indicate general levels of production for the different soil-types, districts and regions, and the quantitative effects of manuring. Thus, the highest yield given by the best soil-type in Trinidad (the Chocolate Soil), is placed at 650 lb. dry cacao per acre, with a production deficit of 67 per cent., while for the best soil-types of the Gold Coast, it is 700 lb. or a deficit of 65 per cent. Actually, from chemical tests and other considerations (18), the Chocolate Soil would be considered to be much superior to the Gold Coast soils, so that the recorded yields for the different soil-types cannot be accepted as truly assessing their inherent soil fertility. *Other factors affecting yields of cacao may evidently be superimposed on the soil-nutrient factor.*

Analysis of Yield Data.

In order to determine the contribution to the total yield made by the individual trees comprising the population of the cacao fields of Trinidad, Prof. C. Y. Shephard has evolved field methods of assessment which have brought to light many unexpected facts. The methods were applied by E. L. Hay (19) to the Rio Claro District of Trinidad to cacao fields comprising both manured and unmanured soil. As an example, the following case may be cited. Out of 100 pickets of a typical 19-year old cacao field on Princes Town Marl Soil at Rio Claro, 29 pickets were found to give no yield at all, 44 to give only low yields (less than 1.1 lb. dry cacao per tree) while the remaining 27 pickets gave profitable returns, and contributed 86 per cent. of the total yield. Of the 29 non-yielders, 13 were blank sites, 5 had been badly damaged by falling Immortel shade trees and 11 had been injured by other causes, such as Canker and Witch-broom diseases. Of the 27 profitable yielders, only 5 produced more than 4.1 lb. dry cacao per tree, and these contributed nearly 25 per cent. of the total yield. From these data, it is evident that the Princes Town Marl Soil is capable of supporting trees yielding at a high rate of production, which implies that the soil is very much better than the average yield for this particular field (253 lb. acre) would appear to indicate.

Results still more striking emerge from an analysis of the tree populations of the control and the treated acre-plots of a phosphate manurial experiment on 19-year old cacao trees growing on Princes Town Marl Soil at Rio Claro. The relevant data are given in Table III, abstracted from Hay's dissertation. The distribution of yield classes is fairly similar in the two plots, and again indicates the high population of non-yielders and low-bearers in each plot (about 80 per cent.). Comparison of yields in 1935-36 and 1936-37, shows that the second season was the more favourable to crop production, the increase in yield of the no-manure plot being 47.8 per cent. The increase for the plot manured at the end of 1936 with superphosphate, 4 lb. per tree, is very much greater than this, namely, 156.6 per cent., of which 108.8 per cent. may be attributed to the direct effect of the manure. The contributions to this large increase made by the different yield-classes shows that it is *mainly borne by the low-yielders.** Thus, the percentage increase due to manuring of the 0.0 to 0.3 lb. per tree class (36 per cent. of the pickets) is 561 per cent., while that of the 0.4 to 0.7 lb. class (22 per cent. of the pickets) is 158 per cent. The yield of the high-bearers has not been much affected by the manuring. Evidently the main cause of low-bearing in the cacao tree population on Princes Town Marl Soil is some soil nutrient deficiency that is partly rectified, either directly or indirectly,† by phosphate manuring. The results suggest that the beneficial effect of manuring in this case is a reduction in pod-shedding, since, in similar circumstances at River Estate, Pound noted an actual increase in the total number of pods as a result of manuring.

* C. Y. Shephard (4) gives the following 9-years average yields, abstracted from estates field records: Chocolate Soil, 693; Brasso Sand and Alluvial Soil, 556; Brasso Clay, 382 lb. dry cacao per acre (Years 1913-1921). Yields have declined since 1921.

Previous to this, an experiment at River Estate in Field No. 2 had demonstrated that 48 per cent. of the tree population had contributed only 4 per cent. of the yield of cacao. These low-bearing trees were replaced by young trees, and 20 years afterwards, the yield of the field had been increased by 76 per cent.

* This result accords with a previous result obtained by F. J. Pound (20) at River Estate, Trinidad.

† McDonald and Rodriguez (*Fourth Annual Rept.*, pp. 75-82) have shown by leaf-ash analysis that where soil phosphate is deficient, the cacao tree is unable to obtain adequate supplies of *potash* from the soil, even when potash is present in abundance.

Table III.

EFFECT OF PHOSPHATIC MANURE ON PRODUCTIVITY OF DIFFERENT YIELD-CLASSES OF CACAO TREES GROWING IN PRINCES TOWN MARL SOIL; RIO CLARO DISTRICT.

(Abstracted from Thesis, I.C.T.A. by E. L. Hay, 1937.)

Yield Class. (lb. dry cacao per tree.)	Control Plot (No Manure).					Manured Plot (Super 4 lb./tree).				
	No. of Pickets.	Estimated Total Yields (lb. dry cacao).		*Increase (lb.)	Per cent. Increase. %	No. of Pickets.	Estimated Total Yields (lb. dry cacao).		†Increase (lb.)	Per cent. Increase. %
		1935-1936	1936-1937				1935-1936	1936-1937		
Blanks ...	24	—	—	—	—	15	—	—	—	—
0.0-0.3 ...	67	5.9	28.1	22.2	376	79	8.6	89.2	80.6	937
0.4-0.7 ...	40	20.8	49.6	28.8	138	47	26.1	103.5	77.4	296
0.8-1.2 ...	33	30.6	56.7	26.1	85	35	34.9	81.6	46.7	134
1.3-2.2 ...	33	52.2	68.2	16.0	31	28	45.7	88.2	42.5	93
2.3-3.7 ...	21	57.7	55.3	− 2.4	− 4	13	38.0	49.3	11.3	30
3.8-6.2 ...	2	9.3	7.7	− 1.6	− 17	3	13.0	14.8	1.8	14
6.2- ...	1	6.9	5.5	− 1.4	− 20	—	—	—	—	—
Totals ...	221	183.4	271.1	87.7	47.8	220	166.3	426.6	260.3	156.6

* Due to age and climate.

† Due to age, climate and phosphate manuring.

In spite of the striking effects of the phosphate treatment, the estimated yield of the Princes Town Marl plot was only raised to 426.6 lb. for 205 trees, an average of about 2.1 lb. per tree, as against 271.1 lb. for 197 trees, or an average of 1.4 lb. per tree for the unmanured soil. In order to yield at the rate of 2,000 lb. per acre, each tree should have contributed over 9 lb. of cacao, instead of 2.1 lb., so that some other factor or factors are limiting the yield of the manured soil. Damage caused by falling shade trees and injury by pests and diseases must be reckoned among these factors, and they may be attributed partly to lack of adequate pruning or neglect of cultivation. The magnitude of their depressing effects on yield, while apparently liable to be very large, has not yet been accurately assessed.

CONCLUSIONS.

(i) Considerations of the chemical status of cacao soils and their responses to specific manurial treatments indicate the undoubted significance of the soil nutrient supply factor, and the relationship appears mainly to concern the general problem of pod-shedding or ripe pod production.

(ii) The fact that a certain, though very variable, proportion of the tree population of any cacao field may be too badly damaged or debilitated by disease to benefit from manurial treatment may prohibit the possibility of raising yields to maximal values.

(iii) Quite apart from this factor, other factors appear to exist that limit cacao production, but they affect certain soils much more than others. Thus, the acidic alluvial clays and the black marl soil of Trinidad seem only to be capable of reaching a relatively low level of production even when suitably manured, while other soil-types, for example, the best alluvial soils of the Northern Range Valleys of Trinidad, and the Roxborough alluvial loams of Tobago, seem to be capable of attaining a very high degree of productivity when suitably manured, and yields approximating to the provisional maximum of 2,000 lb. dry cacao per acre have indeed been recorded for them.

(iv) It may be noted that these high yields have been attained merely by manuring plots of "suitable" soil (mostly sandy types), and that no *substitution has been made in them of high-bearing genetic strains for low-bearers*, though it is conceivable that the fields may originally have been planted with high-bearing genetic strains.

PRINCIPLES OF CACAO MANURING.

Some very interesting facts and principles have emerged from Dr. F. J. Pound's manurial experiments on cacao in Trinidad and Tobago, which form an extension of the field investigations carried out as part of the programme of the Chemical Section of Cacao Research during the years 1932 to 1935. The latest account to be

published in abstract in the 8th Annual Report on Cacao Research, describes experiments which prove that the manuring of the cacao tree may produce unexpected results.

(i) Thus, it has been found that the application of phosphatic manures, while often giving very large immediate increases in yield (up to 100 per cent.) on phosphate-deficient soils, may not continue to give increases of like magnitude for the second or third years, though marked *residual effects* may ensue if they are withheld. Subsequently, the higher level of yield may be maintained by small annual dressings.

(ii) Similar results have been recorded for potash manures applied to potash-deficient sandy soils, but in this case, the annual dosage must not be excessive, otherwise a marked depression in yield may occur.

(iii) This *optimal relationship* of potash manure to cacao yields is unique in the general nutrition of fruit trees, where effective mineral manures, applied in increasing amounts, usually produce corresponding increases in yield. For example, in the manuring of grapefruit, the dressing of mixed artificial manures recommended for application to trees transplanted from the nursery is usually augmented during subsequent years by regular annual increments, so that, at 20 years old, the dressing, may be as much as 60 lb. of mixed salts per tree.

[The difference in manurial requirements between cacao and grapefruit may perhaps partly be explained by the fact that, in the case of cacao, the yield-increase concerns the seeds, while in the case of grapefruit, it concerns the juicy pulp or pericarp, the seeds being unwanted. Furthermore, grapefruit trees are planted much wider apart (say 30 × 30 ft.) and their root system may be more widespread than that of cacao.]

(iv) Another important principle, suggested by the results of Pound's manurial experiments, may be that the best *time to apply manures* to cacao is 5 or 6 months before the main crop is reaped, that is, at the time when the young fruits are setting. (October in eastern Trinidad, May in the western parts.) This again suggests the great importance of mineral nutrition in the question of fruit-shedding which has already been mentioned in an early section of this article.

Harmful Soil Factors.

The occurrence of harmful factors, such as toxic aluminium, organic toxins and undesirable micro-organisms, is usual only in soils that are either very highly acidic or highly alkaline, or badly aerated and waterlogged. Such soils would never grow satisfactory cacao, and would soon be abandoned. In Trinidad, certain clay soils, however, contain *gypsum* (hydrated calcium sulphate) in the surface layers, and appear in consequence to be highly infertile to cacao, and not to respond to mineral manuring. The nearness of the gypseous layer to the surface is generally due to land slips, which may have removed all the nutrient-rich, humic topsoil. Whether the infertility of gypseous soils is caused by excess of sulphate, or by deficiency in available nutrients, for example, nitrogen and phosphate, or perhaps manganese, yet remains to be proved (24).

V. Water Relationships of Cacao.

It is well known that cacao yields fluctuate greatly from one year to another within any given field, district or region, and the fact has been attributed to changing climate or to variable weather. The effect may be assessed from the yield data of the control plots of manurial experiments. The differential response of low-bearing and high-bearing cacao trees to improving weather and manuring has been studied by Pound (20) from the records of a large-scale manurial experiment laid down in 1931 at River Estate.

A previous analysis of yield data for a series of crops at River Estate had demonstrated that good climatic conditions favour the high-bearers more than the low-bearers, so that the variation between the two classes was exaggerated in a good year. This finding was confirmed by the data for the control plots of the manurial experiment, but the data for the manured plots showed the reverse effect. On the other hand, the results given by the control plots of E. L. Hay's experiment (Table III), laid down on quite a different soil-type occurring under a much higher rainfall, showed that the low-bearers benefited most by improved weather conditions, but yet the high-bearers gave proportionately less response to manures (notably potash) in a good year than the low-bearers, just as in the case of the manured plots at River Estate.

In most cases, climatic factors have been regarded as comprising chiefly rainfall (often simply the total annual amount of rainfall), and the correlations that have been established between cacao yields and climate have mainly stressed the depressing effects of excessively wet years on yields, and the consequent alternations of bad- and good-yielding years.

The Rainfall Factor.

Rainfall influences the cacao tree through the media of the soil and the atmosphere, but its effects depend very largely on its distribution over the season, and not solely on its total quantity. The subsequent fate of rain-water falling on a land surface is controlled by three factors, namely, (i) the *nature of the vegetation* (whether open or closed, sparse or dense, arboraceous or grassy), (ii) the *altitude and slope* of the land, and (iii) the *structure of the soil*, which decides its permeability, retentivity and conductance for water. The total amount of rainwater which reaches the land is partly decided by the losses through evaporation from wetted foliage, which may amount to 20 per cent. in the case of forest vegetation. Surface run-off may dispose of a large proportion of the water which reaches the land, according to the degree of slope; its amount also will vary with the kind of vegetation covering the surface.

At the foot of the slope, water tends to accumulate and the moisture conditions in the hollows may therefore be quite different from those on the hills. The penetration of water into the soil depends solely on structure. Moist soil may lose a large amount of water by evaporation and by transpiration of plants that are rooted in the soil.

The water-supply of soil may thus comprise only a small fraction (often less than 20 per cent.) of the total water that falls as rain. The effectiveness of processes such as evaporation from vegetation and soil surfaces, transpiration, run-off and penetration will vary with the intensity of the rainfall and the humidity of the atmosphere, so that the *regularity* of the soil-water supply is greatly influenced by rainfall distribution and periodicity.

The Soil Water-Supply Factor.

Increasing evidence is accumulating to suggest that an unsatisfactory water-supply is often the main reason why many cacao soils are not producing satisfactory crops, not only in Trinidad but also in other countries, including the West African colonies, and why the yields fluctuate so widely from one year to another. These results are not solely due to inadequate or excessive total rainfall, nor to satisfactory rainfall distribution, but partly at least to inherent properties of the soil, as expressed in its ability to deliver water at a suitable rate to the living cacao roots. The *water-supplying ability* of a soil is determined, not only by the amount of available water stored in it, but also by the ease with which this water can move through the soil towards the absorbing plant roots. The conductance of a soil for water depends both on its texture and on its structure, that is on the degree of sandiness or clayiness and on particle aggregation. One extreme case is loose sand, which, though offering little resistance to water movement, may yet store so little water that it requires constant replenishment by rain or irrigation. Furthermore, unless protected from drying winds by effective wind-breaks and ground-cover, sandy soil rapidly loses water by surface evaporation. The Moruga Soils of Trinidad belong to this category, as do also most of the cacao soils of West Africa.

The other extreme case is compact sticky clay, which, though storing large amounts of water, may yet offer so much resistance to water movement that it behaves as if it were relatively dry. If a clay soil possesses an open crumbly structure, however, as is the case when its lime status is good* or its content of humus is large, the conductance for water may be very high. Provided a soil of this sort is protected against excessive drying by the provision of adequate windbreaks, and against waterlogging by the provision of efficient surface drains, it generally possesses satisfactory water-supplying ability under proper rainfall conditions. The Chocolate Soil, the Brasso Calcareous Yellow Soil, and the Princes Town Black Marl Soil of Trinidad, and the upland Andesite Red Soil of Grenada, are good examples of clay soils exhibiting satisfactory water-supplying ability because of good natural structure, but most of the other clay soils of Trinidad are very unsatisfactory.

* It appears likely that the clay soils of Trinidad may best be classified agriculturally on the basis of *lime status* and on *texture*.

Atmospheric Moisture Factors.

The effect of drying winds during early months of the year and of excessive humidity during the wet season in causing excessive harmful fluctuations in the moisture conditions in cacao-fields is well known to planters, who attempt to diminish their violence by growing wind-breaks, over-head shade trees and ground-shade. By these means, the water-relations between the soil, the atmosphere and the plant may be controlled at least within limits. Suitable adjustment is believed to regulate the physiological processes within the plant which result in leaf-flushing, flowering, fruit development, or the wilting and shedding of leaves and fruits. Thus, during the ecological comparison of the "good" and the "bad" plots in Trinidad marked differences were demonstrated, particularly for available soil moisture and evaporating ability of the air. Some representative data are given in Table IV, abstracted from McDonald's annual reports; they clearly show that moisture fluctuations are much smaller in the "good" plot than the "bad", and that this difference is reflected in the somewhat different periodicity in flushing and fruit setting.

It is interesting to note that a start has recently been made in the Gold Coast Colony in an ecological investigation of the cacao tree along similar lines. General observations have already indicated that the moisture relations of the cacao tree in the Gold Coast are perhaps more important than the nutrient relations between the soil and the plant (18). During the harmattan, the relative humidity of the air may decrease from 80 to 60 per cent., the drying effect of the wind being especially noticeable in the north and south-east parts of the Colony (21). On the other hand, in some parts, the humidity of the air constantly attains saturation point for eight or nine months in the year, thus favouring the incidence and spread of Black Pod disease of cacao (22).

Conclusions.

Sufficient has been written to indicate the value of ecological studies by means of measuring instruments applied to plots of cacao having different reputation, but so far, no attempt has been made to trace the effects of moisture fluctuations of the soil and the atmosphere on the *internal* water relations of the cacao tree. How far these may affect the physiological processes favouring fruit development or its converse, fruit shedding, yet remains to be investigated. The effects may be direct, or they may be indirect and closely linked with the manufacture and transportation within the cacao tree of food materials such as carbohydrate elaborated by the leaves. It is intended to study some of these problems in the near future, in continuation of the preliminary ecological work already accomplished.

Table IV.

COMPARISON OF MOISTURE CONDITIONS OF "GOOD" AND "BAD" CACAO SOIL AND ATMOSPHERIC ENVIRONMENTS.

(J. A. McDONALD; 1931.)

	Dry Season, 1931.					Wet Season, 1931.						
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
(A) Available Soil Moisture (Per cent. dry soil).*												
(i) Surface Soil (0-6 ins.)—												
Good ...	8	11	6	8	2	12	19	18	16	12	24	18
Bad ...	15	13	4	6	2	12	15	24	19	19	20	32
(ii) Subsurface (6-12 ins.)—												
Good ...	9	9	5	8	3	10	13	13	12	11	16	12
Bad ...	11	11	1	4	2	11	12	17	16	16	14	19
(iii) Subsoil (12-24 ins.)—												
Good ...	9	9	6	8	5	8	10	13	10	11	13	10
Bad ...	10	9	2	5	1	10	13	15	14	16	13	17
(B) Evaporating ability of Air (cc. per 24 hrs. Livingston Atmometer).												
(i) Lower Stratum												
Good ...	8	10	16	16	14	9	5	6	7	5	4	2
Bad ...	—	—	18	17	23	13	6	6	7	4	4	2
(ii) Upper Stratum												
Good ...	10	12	17	17	17	12	7	9	15	11	9	11
Bad ...	—	—	21	20	23	15	9	9	12	8	9	6
(C) Radiation (cc. 24 hrs.).												
(i) Lower Stratum												
Good ...	1	2	3	3	3	2	1	2	2	1	1	1
Bad ...	—	—	6	5	7	5	4	3	3	3	4	2
(ii) Upper Stratum												
Good ...	8	9	12	11	9	8	6	7	8	7	6	6
Bad ...	—	—	10	7	8	6	6	6	7	5	5	5
(D) Humidity (Per cent. daily average).												
Good ...	71	71	64	68	66	80	82	82	79	85	87	85
Bad ...	—	—	56	60	57	73	82	83	78	84	86	85
(E) Plant Processes.												
Good Plot:												
(i) Leaf flush ...		××	××		××	××	×××		××	×		
(ii) Flower flush ...	×	×			×	××	××	×××	×	×	×××	×
(iii) Fruit set ...							×	×××	××		×××	×××
Bad Plot:												
(i) Leaf flush ...		××	××			×××	×××	××	××	×		
(ii) Flower flush ...	×	×						×××	×	×××	×××	×
(iii) Fruit set ...								××	××	××	×××	×

* Values are gross moisture contents *minus* wilting coefficient value for soil.

VI. Oxygen Relationships of Cacao.

The Soil Aeration Factor.

This factor is probably much more important in cacao cultivation than is generally recognised. In order for roots to exercise their chief physiological function, which is the rapid absorption of water and mineral nutrients, an adequate oxygen supply must be available for respiration, whereby energy is liberated. Without a source of energy, active absorption by roots cannot proceed. Best aeration is provided by soils having an open porous structure. Such soils allow deep penetration by roots, and thus offer a large volume of material from which the plant is able to procure, not only the necessary amount of energy-providing oxygen, but also adequate supplies of water and mineral nutrients.

The close relationship between root penetration, water-supplying ability, acration and soil structure is generally revealed by the features of the soil profile (23). Thus, a compact clay soil that lacks humus and lime and shows a highly acidic reaction, usually allows only shallow penetration by roots, and aeration is confined solely to minute cracks that develop when the soil dries. The cacao root system in such a soil tends to be entirely superficial; consequently the trees are exposed to destructive desiccation during dry weather. On the other hand, arid conditions are necessary for the development of soil fissures, which alone can bring about aeration, so that, unless a cacao clay soil cracks easily, little benefit is derived from the lesser fluctuations of soil moisture such as can be tolerated by the tree.

Conclusions.

It thus seems reasonable to assume that the variations in physical features exhibited by cacao clay soils, by virtue of their different contents of humus, lime, and other effective components, may ultimately decide their suitability to cacao production. Hence their properties should receive careful consideration in the assessment of fertility and in the preparation of soil maps in which the better types are differentiated from the poorer.

VII. Space Relationships of Cacao.

Root Room.

It will be evident from foregoing statements that the physical and chemical features of the soil mainly decide the depth to which cacao roots are able to penetrate and to utilise its moisture, air and nutrient resources. For this reason, soil considerations should form the chief basis for deducing optimum planting distance, and not merely the dimensions of the leaf-canopy. There is urgent need for detailed investigations of the rooting habits of the cacao tree in relation to soil profile features, especially moisture distribution and aeration. Such need has already been recognised in the cultivation of temperate fruit trees and coffee, and similar researches on cacao might aid in removing some of the prejudices against close planting without shade in deep soils having a structure that favours an even moisture, air and nutrient status. The shallower rooting habit of cacao trees growing in some of the compact acidic clay soils of Trinidad, as contrasted with the deeper habit developed in sandy soils such as abound in West Africa, may at least partly account for the apparently greater producing capacity of the land in this region.

Conclusions.

Root studies are notoriously difficult and tedious to carry out, but it is suggested that neglect of this phase of cacao research may prevent the true assessment of the effects of such processes as "root-flush" which may possess considerable physiological significance in growth and pod-production.

VIII. General Methods of Ecological Investigations on Cacao.

The following concrete suggestions are submitted as indicating some of the many promising lines of work on cacao problems deserving immediate attention from research officers.

(A) The procedure already employed in the cacao ecological researches should be further applied to other pairs of *contrasted plots*, for example, the following cases :—

(i) The very high-bearing manured plot at Roxborough, Tobago, and the neighbouring unmanured (or control) plot.

(ii) A sandy-soil plot of cacao situated in the relatively dry north-western peninsula of Trinidad, and a comparable sandy-soil plot situated in the Central Range region, or other district having a relatively high rainfall.

(iii) Two similarly contrasted plots of clay-soil subject to widely different rainfall conditions in Trinidad.

(iv) Two contrasted plots of different soil-types occurring in Grenada (such as Red Earth Soil derived from basic igneous rock, having great depth and a porous crumbly structure), and compact grey clay soil, derived from volcanic ash.

(v) Two or more contrasted plots having different reputations with regard to degree and rate of pod-shedding.

Within each plot, careful periodic records should be kept of the manifestations of physiological processes, such as leaf-flush, flowering, fruit-setting, leaf-fall, fruit-shedding, and, if possible, root-growth. In addition, measurements should be made of the fluctuations of environmental factors, such as soil moisture, atmospheric moisture and available soil nutrients, by modified methods based on previous experience.

(B) Concurrently, detailed investigations should be made of *individual* cacao trees, in order to trace possible relationships between these physiological processes and the chemical composition (both mineral and organic) of different parts of the plant. In these studies, use might be made of salt injection and leaf-spraying methods, whereby the mineral composition of branches or twigs may be altered at will within periods of natural seasonal change. Similarly, ringing and pruning experiments, following on the attempts made by Pound, might be conducted at the same time.

(C) There is need for further field experiments, particularly those that are designed to assess the effects of agricultural operations such as forking, draining, round-ridging, cutlassing, elimination or intensification of overhead shade and of ground shade and pruning. The pioneering attempts in these directions already made under the charge of Dr. F. J. Pound of the Department of Agriculture of Trinidad and Tobago will doubtless be continued, and the results obtained should have considerable value to research workers and cacao growers, not only in Trinidad, Tobago and Grenada, but also in other parts of the tropics where cacao is grown.

IX. References.

(1) (*a*) What is this Agrobiology ? ; O. W. Willcox, *Econ. Forum*, New York, 1936, p. 302. (*b*) Principles of Agrobiology ; O. W. Willcox, Palmer Pub. Corp., New York, 1930.

(2) Hydroponics ; W. F. Gericke ; *Science*, 1937, p. 177 ; also, *Nature*, 1938, p. 536.

(3) Self-Incompatibility of Cacao ; O. J. Voelcker, *Sixth Annual Rept. on Cacao Res.*, 1936, pp. 2-5.

(4) The Cacao Industry of Trinidad ; Some Economic Aspects ; Series II. (Table IX). C. Y. Shephard, I.C.T.A., 1936.

(5) The Progress of Selection, 1933 ; F. J. Pound, *Third Annual Rept. on Cacao Res.*, 1933, pp. 25-28.

(6) The Present Position of Botanical Researches on Cacao ; E. E. Cheesman, *Tropical Agriculture*, XIII, 1936, pp. 123-129.

(7) The Physiology of Cacao, I. General Observations on Growth, Flowering and Fruiting ; E. E. Pyke, *Second Annual Rept. on Cacao Res.*, 1932, pp. 37-40.

(8) Studies in Fruitfulness in Cacao, III. Factors Affecting Fruit Setting ; F. J. Pound, *Second Annual Rept. on Cacao Res.*, 1932, pp. 29-36.

(9) An Environmental Study of the Cacao Tree ; J. A. McDonald, *First Annual Rept. on Cacao Res.*, 1931, pp. 29-38 ; *Second Annual Rept.*, 1932, pp. ii-iv.

(10) Studies of Fruitfulness in Cacao, II. Evidence for Partial Sterility ; F. J. Pound, *First Annual Rept. on Cacao Res.*, 1931, pp. 26-28.

(11) Studies of Fruitfulness in Cacao, V. Conditional Self-Compatibility and its Implications ; F. J. Pound, *Fourth Annual Rept. on Cacao Res.*, 1934, pp. 17-19.

(12) Growth and Abscission in Sea Island Cotton ; T. G. Mason, *Ann. Bot.*, XXXVI, 1922, pp. 457-484.

(13) Fertilization and Embryogeny in Theobroma Cacao ; E. E. Cheesman, *Ann. Bot.*, XLI, 1927, pp. 107-126.

(14) Plant Physiological Work in the Tropics. Some of the Problems with Special Reference to Cocoa, and Some Lines of Attack ; T. G. Mason and E. J. Maskell, *Proc. First Imperial Horticultural Conference*, 1931, Pt. II, pp. 41-45.

(15) A Note on the Behaviour of Cacao Flowers after Pollination, and on the Incidence of Cherelle Wilt ; O. J. Voelcker, *Seventh Annual Rept. on Cacao Res.*, 1937, pp. 5-8.

(16) Self-Incompatibility in Cacao II ; O. J. Voelcker, *Seventh Annual Rept. on Cacao Res.*, 1937, pp. 2-5.

(17) Cacao ; A Summary of Literature since 1931 ; O. J. Voelcker, *Seventh Annual Rept. on Cacao Res.*, 1937, pp. 20-30.

(18) Some Gold Coast Cacao Soils—Series II ; F. Hardy and E. H. Amoroso-Centeno, *Seventh Annual Rept. on Cacao Res.*, 1937, pp. 32-40.

(19) A Re-investigation of the Factors Influencing the Yield of Cacao in the Rio Claro District ; E. L. Hay. Unpublished Dissertation in part fulfiiment of the Requirements for Associateship, I.C.T.A., 1937, pp. 51 (Typescript).

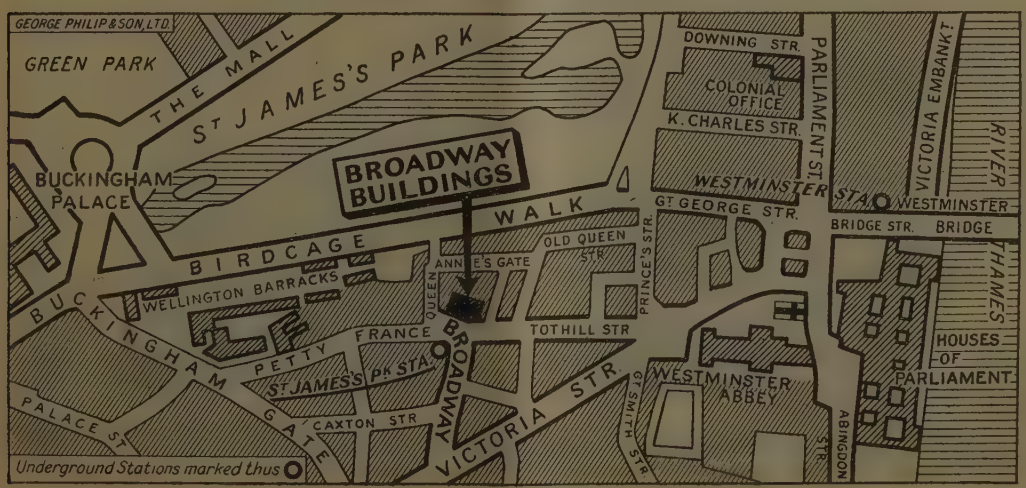
(20) Studies of Fruitfulness in Cacao IX. Differences between High-bearing and Low-bearing Cacao Trees in Response to Inorganic Manures ; F. J. Pound, *Fifth Annual Rept. on Cacao Res.*, 1935, pp. 20-21.

(21) The Harmattan and Atmospheric Humidity ; N. P. Chamney, *Year Book*, 1928, Dept. Agric., Gold Coast, *Bul.* 16, 1929, pp. 286-288.

(22) The Determination of Incidence of Black Pod Disease of Cacao ; H. A. Dade, *Year Book*, 1930. Dept. Agric., Gold Coast, *Bul.* 23, 1931, pp. 122-128.

THE NEW COLLEGE LONDON OFFICES.

THE plan below shows the position of the new offices of the Imperial College of Tropical Agriculture. These offices, formerly housed at 14, Trinity Square have recently been removed to Broadway Buildings, Westminster, S.W.1., and are conveniently situated near the Colonial Office and the St. James' Park and Westminster Underground Stations.



PINEAPPLE PROPAGATION.

A New Method in Sierra Leone.

By H. Macluskie.
(*Agricultural Officer, Sierra Leone*).

Introduction.

Some years ago a new method of propagating pineapples was fully described in this Journal.* The method was evolved by Walters, then Agricultural Superintendent of St. Lucia, and with special nursery conditions produced astonishing results. In this method the stems of pineapple plants were stripped of their leaves and thoroughly cleaned. They were then transversely cut into cross sections or discs and planted on specially prepared nursery material, with the result that dormant and semi-dormant buds on the perimeter were induced to germinate.

This method was attempted at Newton with unsatisfactory results, but the Newton soil is poor and no special nursery medium was prepared, the beds being merely well forked and supplied with a moderate amount of organic manure in the form of decayed vegetable matter. The mortality among the discs was comparatively high and many of the plantlets died after transplanting. The result was that Queen and Red Spanish varieties only yielded 7 to 8 plantlets per stem and Smooth Cayenne as few as 1 to 2.

New Method.

In March this year (1938) the writer attempted a new way of utilizing pineapple stems for propagation which has given very promising results. The stem was stripped, cleaned in the usual way and cut *longitudinally*, instead of transversely, into quarter slices. These slices exposed a large outer bud-bearing surface, each slice bearing its own reserve of food from the interior of the stem. The inner surface of the pith was then pared flat and the slices placed outer surface uppermost upon a nursery bed of well forked soil and humus and pressed half way into the soil. It was found that within a week the stronger buds had swelled and in three weeks little plantlets, strong in character, had developed. As soon as these were large enough (4 to 8 weeks), the plantlets were cut away with a small piece of the parent slice, the suckers by that time having become well equipped with rootlets. These plantlets required further nursing until old enough for their permanent place in the field. After the first crop of suckers was removed, the slices were replaced in the nursery for the further development of plantlets.

From the first stem tried, 18 plants were obtained. In view of this result the method was further tested and has now become the ordinary practice at Newton.

Between March and December, 1938, over 4,200 plants were raised and only the shortage of pineapple stems limited propagation to this figure.

The average multiplication per stem showed an encouraging increase by this method. With the Queen variety an average of 17 plants per stem, with a maximum of 25, was obtained, whilst with Smooth Cayenne and Baron de Rothschild, notoriously difficult varieties to propagate, an average of 5 and a maximum of 8 plants per stem have been raised.

Certain points are worthy of comment. Plants which are in an advanced state of fruiting are unsuitable for propagation by this method. It has been found that the best time to cut the stem is when the plant is fully grown and just about to flower; after that the rate of multiplication declines.

During the rains, germination, although somewhat slower, is quite successful. Shade is unnecessary during the rains, but is advantageous during the dry months.

The slices may be soaked in permanganate of potash as done in St. Lucia, to prevent ants attacking them when placed in germination beds. They should not, however, be covered over, but left exposed for the free development of buds as shown in the accompanying photographs.

The preparation of the nursery presents no difficulty and is simply a well forked soil with the incorporation of well rotted humus of well decomposed cow manure.

* Walters, E. A.—Plant Propagation, *Tropical Agriculture*, Vol. IX, No. 2, pp. 35-37, 1932.

SOIL DECOMPOSITION OF A PLANT PATHOGEN.

Several fungi which attack plants from the soil disappear when the host is not grown for a certain period. S. D. Garrett, of Rothamsted Experimental Station, has made a study of this action with *Ophiobolus graminis*, the fungus causing 'take-all' disease of wheat (*Ann. App. Biol.*, 25, No. 4, 742; 1938). The fungus apparently disappears as a result of natural decomposition by other micro-organisms of the soil. It will remain alive indefinitely in air-dry soil, at low temperatures of 2-3°C., and under sterile conditions. Decay of *Ophiobolus* mycelium is quickest when conditions are such that the normal micro-flora of the soil is greatest. Addition to the soil of energy materials lacking nitrogen, such as glucose or starch, hastens the destruction of mycelium, whilst dried blood, with readily available nitrogen, has the opposite effect. Soil conditions which are least favourable for the parasitism of *O. graminis* may, in fact, best preserve the organism during the non-pathogenic phase.—(*Nature*, Vol. CXLIII, No. 3621, p. 526, 1939.)

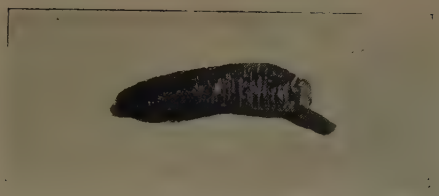


FIG. 1.

FIG. 2.

FIG. 3.

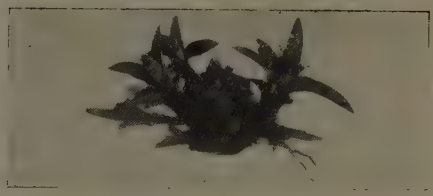


FIG. 4.

FIG. 5.

FIG. 6.

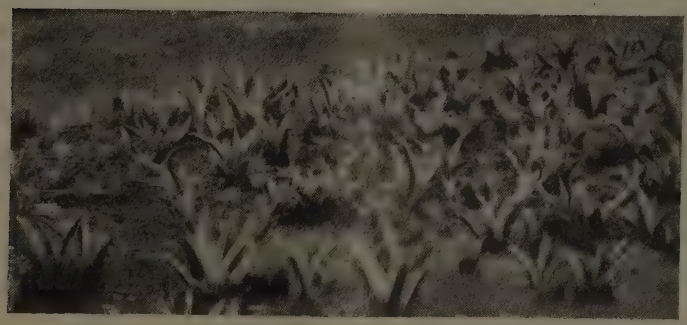


FIG. 7.

FIG. 8.

FIG. 1.—Stem prepared for slicing. FIG. 2.—Stem sliced into four quarters, showing outer bud bearing surface and triangular inner ridge which requires paring. FIG. 3.—Nursery bed. Slices in position. FIGS. 4 & 5.—Germinated slices with plantlets ready for removal. Rootlets are noticeable. FIG. 6.—Slices with plantlets four to six weeks old. FIGS. 7 & 8.—Transplanted nurseries five months old.

IMPERIAL COLLEGE OF TROPICAL AGRICULTURE.

STAFF AND STUDENTS, 1938-1939.

Sitting Left to Right.

1st Row.—C. M. SALAZAR, I. E. JOHNSON, L. LYNDON KERR, G. A. SOUTHWELL, G. BADLEY, C. BRADSHAW, K. N. BARNARDO, H. K. SHANNON, P. D. SMITH, C. W. FITZWILLIAM, J. W. T. DUNLOP, M. R. CUKE.

2nd Row.—D. D. PATERSON, C. C. SKEETE, G. G. GIANETTI, J. G. DAVIES, A. M. ADAMSON, E. HARRISON, E. MACFADYEN, O. T. FAULKNER, F. HARDY, C. Y. SHEPHARD, E. E. CHEESMAN, R. E. D. BAKER, C. W. WARDLAW, C. T. WATTS, G. R. LANGDALE.

Standing Left to Right.

1st Row.—G. E. L. SPENCER, L. A. CORBIN, R. E. D. YEARWOOD, H. R. BARNELL, G. RODRIGUEZ, A. L. JOLLY, E. C. HUMPHRIES, H. F. BIRCH, L. J. C. EVANS, E. McC. CALLAN, K. S. DODDS, F. W. COPE, E. R. LEONARD, S. H. CROWDY, A. D. T. MONTAGU.

2nd Row.—P. A. GETHING, R. J. W. GRIMM, C. B. JOHNSTON, H. W. T. WEBB, M. LUNAN, T. A. PHILLIPS, M. A. G. HANSCHELL, G. SAENZ, R. K. McKEE, C. MANSFIELD, P. G. D. BETHELL, S. GRAY, G. J. B. MURRAY.

3rd Row.—M. D. FFRENCH-MULLEN, B. O. OGUNNIYA, F. O. T. JAMES, W. A. FLOOK, J. M. SMITH, F. H. ORMEROD. F. J. SMART, K. STRZEMIENSKI, R. W. RAYNER, G. S. COWLEY, C. J. DAWKINS, R. SMITH, H. T. FOSTER, T. CHINLOY, J. G. SMITH.

4th Row.—E. D. WELLER, J. S. C. BARRERA, J. B. STOLLMEYER, C. D. M. CLARKE, L. H. LORD, E. G. B. JONES, L. H. McNEILL, C. G. MUNRO, M. S. SAMPATH, H. T. CARRINGTON, G. B. KENNARD, P. POONAI, W. A. SPENCE, W. A. ROSE.

Back Row.—G. M. BRYANT, S. C. SHILLINGFORD, H. H. BEACH.

Absent.—W. RYLE DAVIES, J. PAINE, D. B. MURRAY, H. VINE, J. R. BROWN, B. A. BITTER.

MISCELLANEOUS NOTES.

Cultivation of Roselle Fibre in Java.

In a note* on roselle fibre (*Hibiscus sabdariffa*) reference was made to the attempts to develop the cultivation of the plant in the Netherlands East Indies. The following account of the prospects of the crop for cultivation by natives is taken from a translation of a statement by the local government kindly furnished to the Imperial Institute by the Department of Overseas Trade.

Roselle is grown in Java only on a limited scale on the European estates and the cultivation is still to a considerable extent of an experimental nature as regards the cultivation technique, as well as the fibre production and the sale of the product.

From the results obtained so far by the estates, the impression has been received that roselle is a crop which needs a lot of water, not only from the point of view of cultivation but also for the fibre production. With regard to the time it takes to grow, which is from seven to eight months, this crop can only be successfully grown by the native population on their rice fields if they have sufficient irrigation water at their disposal during the east monsoon.

Roselle moreover needs good soil, while to obtain a product of good quality great care has to be given in its cultivation.

It will take the entire west monsoon and part of the east monsoon to grow roselle, which makes it almost impossible to grow other crops on the fields. Especially in districts where there is no, or only a slight, surplus of food products, the cultivation of such a crop, which occupies the land for such a long time, and the sale of which is not yet sufficiently assured, carries with it a risk for the supply of food.

Apart from the estates which make their own bags from the roselle fibre grown on the estate, the sale of this product—still little known on the world market—is not sufficiently certain. This applies in particular to the inferior qualities of fibre which would be produced eventually in larger quantities by the native growers than the European estates.

The cultivation of roselle for export by native growers would, even if they are conversant with the technique of the cultivation and the preparation of the fibre, most certainly leave a loss at present quotations.

Whether the cultivation by natives would be a paying proposition if they were able to sell their fibre to bag factories which might eventually be established in Java, is still problematical.

In connection with the above it is not possible to give an affirmative reply to the question whether the cultivation is a paying proposition for native growers.

This matter is nevertheless having the continual attention of the authorities.

* *Bulletin of the Imperial Institute*, XXXV, p. 465, 1937.

The General Agricultural Experimental Station is making regular experiments on their fields with the cultivation of this crop, while a study is being made of the sales possibilities of roselle fibre. If these experiments, as well as those on the estates, offer some prospects for native cultivation, experimental fields will be laid out in the most suitable districts in co-operation with the native population.—(*Bulletin of the Imperial Institute*, Vol. XXXVII, No. 1, pp. 34-35, 1939.)

* * *

I. Seed Selection of Coconuts. II. Nursery Management and Selection of Seedlings.—*By W. V. D. Pieris.*

I. Selection for propagation on coconut estates should consist of selection of (*a*) mother palms, (*b*) of seed nuts. In palm selection the characteristics sought should be a straight, stout trunk with leaf scars close together and short, evenly dispersed fronds; the bunch stalks should be short and show no tendency to droop, the inflorescences uncrowded with female flowers or button nuts (up to 100 is satisfactory): inflorescences in all stages should be visible on the palm carrying their full complements of developing nuts. Heavily loaded lower bunches may conceal deficiencies higher up. The best criteria are the number of nuts and the weight of the husked nut, which should be high. Palms growing in unusually favourable sites should not be selected. Yield records of the selected trees must be kept for at least three years. The weight of copra should be approximately equal to 32 per cent. of the weight of husked nuts. After three years all selections that have not produced 100 nuts and 175 lb. of husked nuts per annum should be discarded. In nut selection only fully ripe nuts should be used, preferably from the first bunch. II. Nuts should first be germinated in nurseries in raised beds of light well-drained soil near to a water supply and if possible to the site of their future planting. It is advisable, though not always possible, to transplant before the roots have penetrated the husk and entered the soil, that is when the shoot is four to six inches long, in which case spacing in the nursery beds may be from 9 to 12 inches. Nuts should be planted flat on one side, this position reducing risks from drought and ensuring a more robust plant than upright planting. For selection at least 50 per cent. more nuts than the required number of seedlings should be sown. Selection for transplantation should be for early germination, rapid growth and sturdiness. The two last are not apparent until the first two or three green leaves have developed. Mention is made of diseases and pests by which seedlings may be attacked and of possible control methods.—(*Imp. Bur. of Hort. and Plantation Crops*, Vol. VIII, No. 1, Abs. 256, pp. 72-73, 1938.)

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

Analytical and Control Methods for Use in the Manufacture of "Invert Molasses".

(a) By R. E. Diago and M. A. Mascaro, (b) By J. C. Gonzalez and F. Guerrero. Proceedings of the Eleventh Annual Conference of the Cuban Sugar Technologists' Association, pp. 43-53.

(*a*) These two members of the Committee appointed by the Association to consider control methods for use in the manufacture of inverted syrups and molasses had as their object in view a simple scheme capable of being carried out by the ordinary laboratory personnel to be found in any Cuban sugar mill.

It is based on the two stages which comprise the manufacture of inverted syrups and molasses: (1) the ordinary procedure as far as obtaining the uninverted syrup, the losses in the bagasse in the filter-press cake, and undertemined, being shown as usual; (2) which starts with the uninverted syrup and finishes with the inverted molasses finally obtained, this phase being based on the determination of the total sugars (Clerget plus glucose).

A practical example is given, part of which only may be reproduced here. In estimating the total sugars obtained or recovered in the manufactured molasses consideration is given to the amount of invert sugars gained as a result of the sucrose inversion, since 100 parts of sucrose yield 105.26 parts by weight of invert sugars. Here is the statement giving the total sugars available and obtained in the example presented:—

Total Sugars available.	*Arrobas.*
Clerget in the uninverted syrup ...	332,214
Invert sugar gained by inversion ...	12,477
Glucose in uninverted syrup... ...	20,013
	364,704

Total Sugars obtained.	*Arrobas.*
Clerget in the inverted molasses made...	95,009
Invert sugars in the inverted molasses made	253,281
	348,290

Hence total sugars lost 364,704—348,290=16,414; and the retention of total sugars is 348,290 × 100/346,704=95.50 per cent. The Munson and Walker method is put forward for the determination of the invert sugar, it being the method used by the U.S. Customs.

(*b*) This scheme of control is more elaborate, and requires an exact knowledge of the reducing sugars entering into the manufacture, either as natural glucose or as sucrose, the latter being calculated as glucose. It also calls for the ratio between the total glucose and the real solids entering into process, the final product, the inverted molasses, being graded but its coefficients of sugars and non-sugars per cent. total dry matter or true solids.

Production data stated are: yield in gallons per cent. cane; gallons of 85° Brix per cent. cane; lbs. total sugars per gallon; total sugars in molasses at 85° Brix; and the coefficient of total sugars to Brix. These authors also recommend that the amino acids should be determined, and they use Riffart's method, as described by Ambler.—(*Int. Sugar Jr.*, Vol. XLI, No. 486, p. 232, 1939.)

* * *

Manufacture of Sulphitation Sugar from Dark Coloured Canes (as Purple Mauritius) using Aluminium Hydroxide for Clarification—*By S. Venkata Ramanayya.*

Purple Mauritius would be an attractive cane for the production of sulphitation white sugar if it were not for the fact that its juice, after being clarified in the usual way by liming and sulphuring, has a red colour, and yields a dark coloured sugar. This difficulty, however, the author has found may be overcome by the use of aluminium hydroxide for the adsorption of the anthocyanin pigment from the juice, and large-scale experiments were carried out at the Etikoppaka Sugar Factory in the following way: juice was limed cold to 8.8 pH, and after thoroughly stirring was sulphured to neutrality, at which stage alumina cream was added at the rate of ¼ to ½ gallon per 200 gallons of juice, the whole being thoroughly mixed together. After concentration, the syrup was sulphured to a pH of 6.0 to 6.5, and boiled to grain with from ½ to 1 lb. of sodium hydro-sulphite per ton of sugar produced. "Bright lustrous sugar" completely devoid of colouring matter and colloidal particles was thus obtained. "It can now be definitely stated that aluminium hydroxide is a powerful decolorizer for the juice of the Purple Mauritius cane, and when judiciously applied to limed and sulphited juice produces excellent sugar". On an average only 1 lb. of commercial alum was required per ton of cane.—(*Int. Sugar Jr.*, Vol. XLI, No. 486, p. 242, 1939.)

* * *

"Canite."

The Building Materials Division of the Colonial Sugar Refining Co., Ltd., of Sydney, Australia, have erected a factory at Pyrmont on a water frontage of 600 feet, adjoining the refinery there, where all grades of building boards under the trade name of "Canite" will be made. The building will be of reinforced concrete throughout, and will include a main 2-storey building, 590 feet long × 63 feet high × 65 feet wide, designed for straight line production and warehouse handling, and in addition there will be a multi-storey wing 82 × 80 × 83 feet high in which the preparatory manufacturing processes will be carried out.—(*Int. Sugar Jr.*, Vol. XLI, No. 486, p. 230, 1939.)

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

Relationship between Chemical Composition of Corn Plants and of Culture Medium.

THE uptake, transportation and utilisation of the various chemical elements controlling plant growth has long interested agricultural chemists who have attempted to correlate these processes with responses of crop-plants to manurial treatments by means of periodic chemical analyses of leaf material or other parts of the plants. The following results refer to a comprehensive investigation of this sort, carried out at the New Jersey Agricultural Experiment Station, by Drs. J. R. Beckenbach, W. R. Robbins and J. W. Shive, and described in *Soil Science*, 1938, 45, pp. 403 to 426. (Nutrition Studies with Corn : II.)

Corn plants were grown in sand cultures in which were used a series of nutrient solutions with different proportions of the essential ions, potassium, calcium, magnesium, phosphate, nitrate and sulphate. Leaf and stem tissues from each treatment were harvested separately, and each fraction was analyzed for soluble and total content of potassium, calcium, magnesium, phosphorus, nitrogen and sulphur. The data were analyzed statistically in order to determine the relation between the concentration of the nutrient ions in the substrate and their rates of penetration and accumulation in the tissues of corn plants.

It was found that the most important single condition concerned with the penetration and accumulation in the plant tissues of each of the elements investigated, is its *absolute concentration* in the nutrient solution. It was further found that the content of any element in the tissues may be directly or inversely related to the concentration of other elements in the substrate, depending upon certain of their known chemical properties and the nature and degree of their physiological importance. Many of the interrelations between the accumulation of elements in the tissues and ionic substrate concentrations support the hypothesis suggested by Hoagland *et al.* of ionic penetration, whereas others apparently fail to do so.

The general trends of these relations in stem tissues and leaf tissues are very similar, although the order of magnitude of values differs considerably. Some of the more important specific relations indicated by means of the statistical treatment of data are briefly summarized below. Within the range of ion concentrations in the culture here employed: *Magnesium content* of corn tissues was directly related to variations in the nitrate and calcium-ion concentrations in the substrate, high magnesium content corresponding to high nitrate and high calcium-ion concentrations, and low magnesium content corresponding to low concentrations of these ions ; magnesium content of the tissues was affected in the opposite way by variations in the potassium-ion concentrations. Magnesium contents of the tissues were unaffected by variations in the phosphate and sulphate-ion concentrations. *Calcium content* of corn tissues was directly affected by variations in the nitrate-ion concentrations in the substrate, high calcium content being associated with high nitrate-ion concentration and low calcium content with low nitrate-ion concentrations, but was unaffected by variations in the concentrations of other ions in the substrate. *Potassium content* of corn tissues was inversely related to variations in nitrate and calcium-ion concentrations in the substrate, high potassium content to low concentrations of these ions and *vice versa*, but appeared to be comparatively unrelated to variations in the substrate concentrations of other ions. *Nitrogen content* of corn tissues was inversely affected by variations in concentrations of potassium and calcium-ions in the substrate, high nitrogen content being associated with low concentrations of these ions and *vice versa*. Nitrogen content of tissues was unaffected by variations in the concentration of other ions. *Phosphorus content* of corn tissues was relatively unaffected by variations in the concentration of any of the nutrient ions in the substrate except by those of the phosphate-ion itself. *Sulphur content* of corn tissues was inversely related to variations in the concentrations of calcium and nitrate-ions in the substrate, high sulphur content corresponding to low concentrations of calcium and nitrate-ions in the substrate, and low sulphur content corresponding to high calcium and nitrate-ion concentrations ; the sulphur content was relatively unaffected by variations in the concentrations of other ions.

* * *

pH for Healthy Growth in Citrus.—*By A. R. C. Haas.*

As a result of studies, which are described, it is concluded that citrus can grow under alkaline conditions when the nitrogen is added to the solution in the form of calcium nitrate and that the active growth of citrus roots in such cases will reduce the degree of alkalinity. In certain types of alkaline soils citrus roots can change the pH about them so as to secure adequate nutrition; in other types of alkaline soils the assistance of acid supplements may be needed. Depending on the stage of the absorption process the roots may also increase the alkalinity. The change in a solution brought about by the roots may not be to the pH best suited to healthy growth. Root rot is often attributed to lack of aeration from one cause or another. In these experiments root rotting occurred when the pH remained near 8.1, although an abundant supply of air was run continuously through the culture solutions. Vigour was quickly restored to such of these rotting roots as remained alive by the addition of sufficient acid to the culture.—(*Imp. Bur. of Hort. & Plantation Crops*, Vol. VIII, No. 1. Abs. 176, p. 53.)

TREND OF THE MARKETS.

[The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices are spot, London.]

SUGAR.—Prices on the Home Market have ranged as follows (c.i.f.per cwt.) :—

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
1st June	7	6	11	9
8th June	7	3	11	0
15th June	7	3	11	0
22nd June	7	9	11	3
29th June	8	3	12	0
6th July	8	3	11	9
13th July	8	3	11	0
(14*th July*, 1938) ..	5	5¼	9	3

On 13th June the International Sugar Council approved an increase of 153,265 metric tons in the British Dominion and Colonial quotas, and an additional quota of 7,000 tons to Haiti. This step means that the total quotas have been increased by 399,265 tons to meet an estimated shortage of 480,000 tons. It is still uncertain whether Russia will use her allotment of about 66,000 tons and if she elects to surrender it the reallocation will cause further delay. The market which has been rather sluggish has been decidedly firmer since the Council's decision was made, the raw market being particularly active.

* * *

RUBBER.—Quotations for Plantation Sheet have ranged as follows :—

	Pence per lb.
2nd June	8 5-16
7th June	8 1-4
14th June	8 3-16
21st June	8 1-4
28th June	8 1-4
5th July	8 3-16
12th July	8 1-4
(13*th July*, 1938)	7 3-8

Although political tension is again a predominant feature the market has remained firm. American consumption for May at 44,377 tons is regarded as satisfactory. There has also been a steady demand for rubber from the continent.

* * *

LIME PRODUCTS.—*Lime Oil*—Hand pressed is scarce at present, and the value has increased by 2*s.* 6*d.* to 27*s.* 6*d.* to 30*s.* per lb., according to quality. Distilled remains steady but quiet and unchanged at 11*s.* 6*d.* per lb., sellers on the spot. *Lime Juice*—Concentrated is still not in demand. Raw is quoted nominally at 1*s.* 9*d.* to 2*s.* 3*d.* according to quality.—(*West India Committee Circular*, 29th June, 1939.)

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association.

	American Mid.	*Egyptian Giza.*	*F.G.F. Sakel.*
2nd June ..	5.49	6.67	6.57
9th June ..	5.77	6.79	6.69
16th June ..	5.76	6.73	6.63
23rd June ..	5.66	6.61	6.51
30th June ..	5.62	6.56	6.46
7th July ..	5.61	—	—
14th July ..	5.52	—	—
(15*th July*, 1938) ..	4.88	7.30	7.35

One feature of interest has been the decision of the government to place further cloth contracts, totalling 20 million yards. Raw cotton prices have continued to advance owing to less favourable weather reports from the American Belt when the new crop is said to be making an indifferent start. A retail business has taken place in West Indian Sea Island Cotton at steady rates.

A few small sales of West Indian Sea Island Cotton have taken place at steady prices.

* * *

COCOA.—Since last writing there is very little change to report on the cocoa market. The absence of a more aggressive demand, notwithstanding present low prices, may appear to be caused by the general stalemate existing in most markets. An equally, if not more important factor, is the cumbersome supply situation, and the rapidly approaching New Bahia and New Main Accra crops must also be considered. While more important arrivals of these crops into consuming centres are still a few months ahead recent short sales will soon have to be absorbed in much larger quantity. Accra new crop is quoted at 20*s.* 6*d.* and locally $8.00 a fanega is paid for Plantation marks.—(*By courtesy of The Cocoa Planters' Association of Trinidad, Ltd.*)

* * *

COPRA.—Value has eased. The price of *f.m.s.* on the spot is £10 15*s.* 0*d.* as against £11 10*s.* 0*d.* and the same figure is quoted for forward shipments.

* * *

BANANAS.—Good demand for Jamaicas. Prices have risen by £1 5*s.* to £20 15*s.* delivered London, and £20 10*s.* delivered nearest Station Provinces. Brazilians : fair demand with prices at £16 10*s.* delivered London and £16 delivered Provinces.